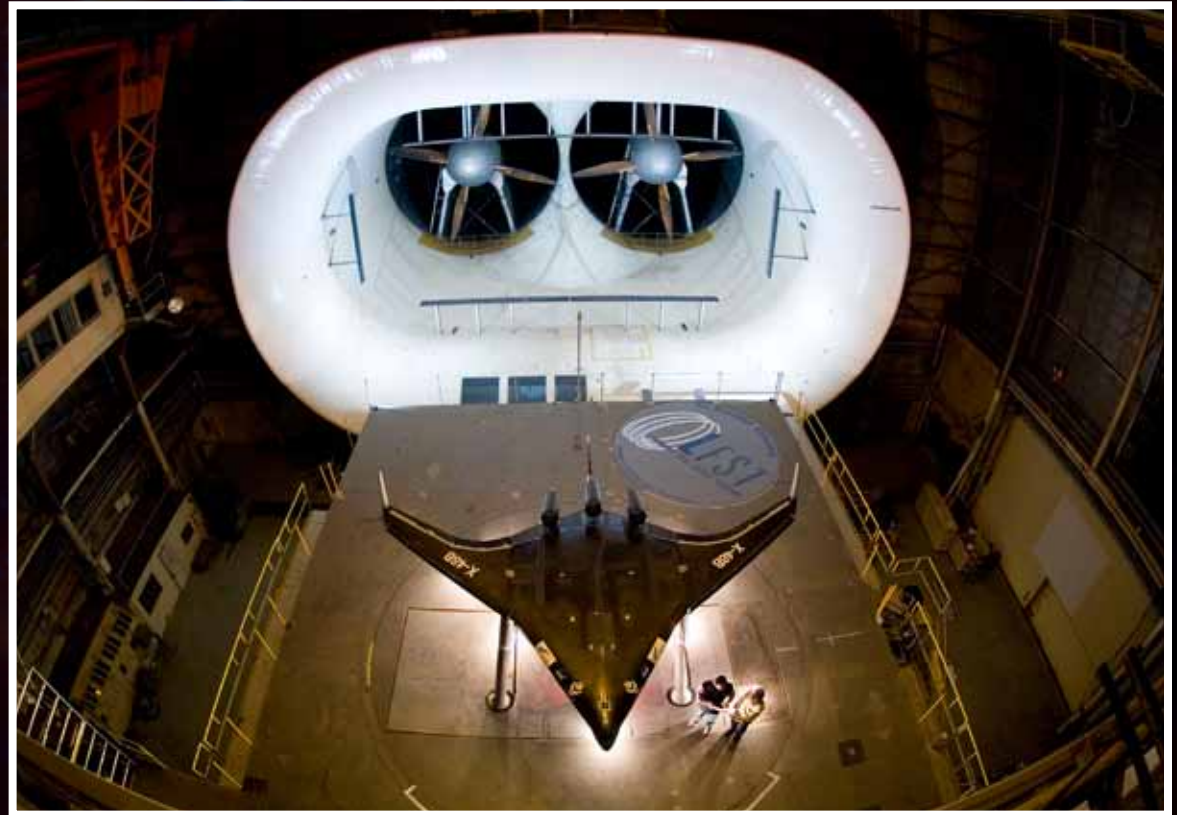




Aeronautics Research Mission Directorate

Small Business Innovation Research Technology Investments in Aeronautics Research



**National Aeronautics and Space Administration
Aeronautics Research Mission Directorate
Small Business Innovation Research
2009 Phase 2 Technology Investment Portfolio**







Foreword

Technological innovation is the overall focus of NASA's Small Business Innovation Research (SBIR) program. The program invests in the development of innovative concepts and technologies to help NASA's mission directorates address critical research and development needs for agency projects. The SBIR program works with the Aeronautics Research Mission Directorate (ARMD) to enhance its core research areas: aerodynamics, materials and structures, propulsion, dynamics and control, advanced computational and mathematical techniques, and experimental measurement techniques.

This technology investment portfolio highlights innovative SBIR 2009 Phase 2 projects that address specific technology gaps within ARMD. Brief descriptions are provided for 43 research and development efforts in ARMD's four key technology areas: Aviation Safety, Fundamental Aeronautics, Airspace Systems, and Aeronautics Test Technologies. All abstracts can be found online at www.sbir.nasa.gov.





Small Business Innovation Research

The Small Business Innovation Research (SBIR) program gives small high-tech companies and research institutions the opportunity to participate in government-sponsored research and development (R&D). Under the program, NASA benefits from a cost-effective way to infuse technology into its missions, and small businesses benefit by developing technologies with commercial potential. The highly competitive, three-phase SBIR award system provides qualified small businesses, including women-owned and disadvantaged businesses, with opportunities to propose unique ideas that meet specific research and development needs of the federal government.

Phase 1 is a feasibility study to evaluate the scientific and technical merit of an idea. Awards are for periods of up to 6 months in amounts up to \$100,000.

Phase 2 contracts further pursue the developments achieved in Phase 1 and focus on the development, demonstration, and delivery of the proposed innovation. Awards are for periods of up to 2 years in amounts up to \$600,000.

Phase 3 contracts are for the commercialization of the results of Phase 2 and require the use of private sector or non-SBIR federal funding.





Aeronautics Research Mission Directorate

The Aeronautics Research Mission Directorate (ARMD) conducts cutting-edge, fundamental research in traditional and emerging disciplines to develop technologies for safer aircraft and higher capacity airspace systems and to support future air and space vehicles. The goals of the directorate are to improve airspace capacity and mobility, aviation safety, and aircraft performance while reducing noise, emissions, and fuel burn. At ARMD, aeronautics research is organized into four separate programs: Aviation Safety, Fundamental Aeronautics, Airspace Systems, and Aeronautics Test Technologies.

Aviation Safety

The Aviation Safety Program (ASP) explores issues associated with making an already safe air transportation system even safer. Research focuses on ways to further reduce risk in a complex, dynamic operating domain. In addition to providing fundamental research into known safety concerns when requested by the aviation community, ASP works with its partners to address the challenges created as the nation transitions to the Next Generation Air Transportation System. Challenges include significant increases in air traffic, continued operation of legacy vehicles, introduction of new vehicle concepts, increased reliance on automation, and increased operating complexity.

Fundamental Aeronautics

The Fundamental Aeronautics Program (FAP) conducts long-term, advanced research in all flight regimes to address the major challenges of modern air transportation: public concern over noise and emissions; the sustainability of affordable air travel given the fluctuating cost and availability of jet fuel; requirements for increasing mobility to meet the growth of air transportation by 2025; and the need for progress toward faster air transportation. FAP also conducts research associated with air-breathing access to space and entry and descent into planetary atmospheres to support NASA's space exploration vision.

Airspace Systems

The Airspace Systems Program performs foundational research to enable the development of revolutionary improvements to, and modernization of, the National Airspace System. This research seeks ways to allow existing aircraft to reduce their environmental impacts and take advantage of the improved, modern air traffic management system.

Aeronautics Test Technologies

The Aeronautics Test Program (ATP) ensures the capability, availability, and accessibility of an extensive suite of test facilities to meet NASA and other U.S. aeronautics needs. NASA, other government agencies, and commercial customers use ATP ground and flight test capabilities to test and demonstrate new technologies, materials, structures, and flight concepts and to explore and understand aeronautical behaviors and phenomena.

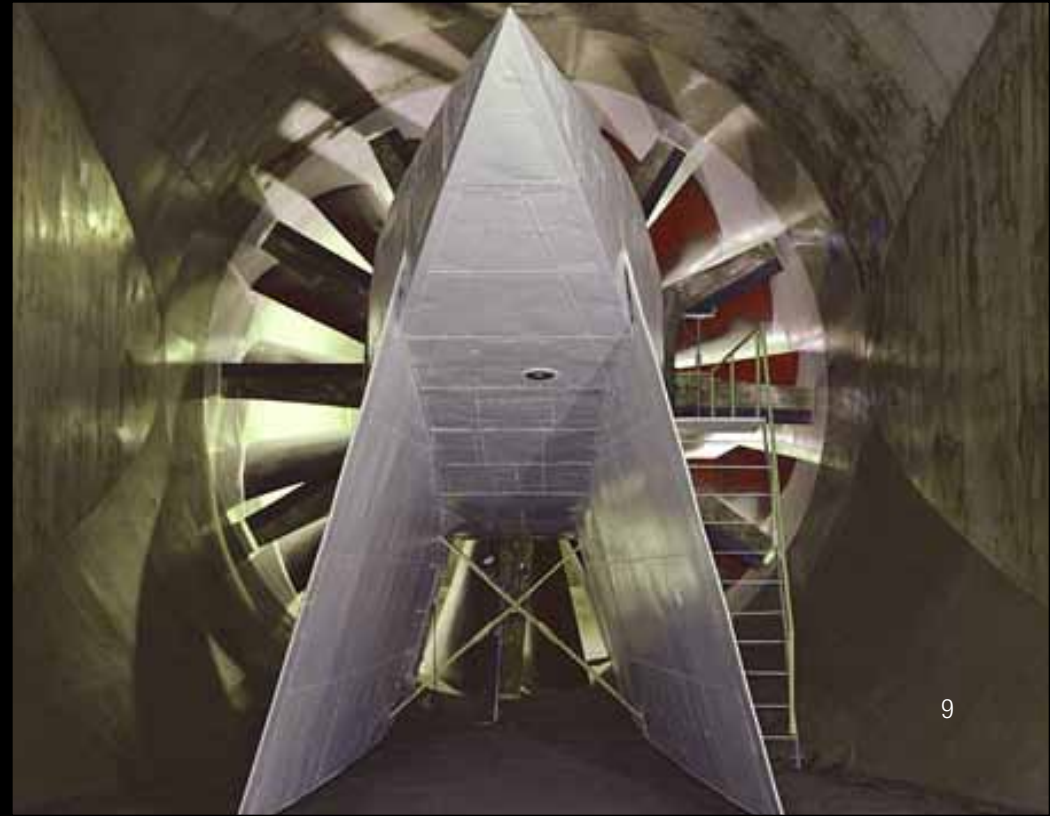


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AVIATION SAFETY PROGRAM

The Aviation Safety Program (ASP) focuses on predicting and addressing aviation safety challenges of the future. Sustained scrutiny is essential in order to meet the projected increases in air traffic capacity and realize the new capabilities envisioned for the Next Generation Air Transportation System. ASP works to monitor safety issues inflight and lessen their impact should they occur, analyze and design them out of complex system behaviors, and constantly evaluate designs and operational data for potential hazards. The program focuses on a foundational approach to advancing knowledge in the core disciplines of fluid dynamics, computational methods, and material science and builds integrated multidisciplinary system-level models, tools, and technologies.

Research areas include:

- Studying the durability and aging characteristics of advanced composites and metals
- Developing more ways to predict and manage the overall health of an aircraft in flight and through data mining after the flight
- Evaluating how to lessen the effects of aircraft upset and un-commanded loss of control
- Providing a vision, design methods, and analysis tools for properly integrating human contributions to safety in the flight deck of the future



Automated NDE Flaw Mapping System

INNOVATION

NASA's Aircraft Aging and Durability Project (AADP) aims to ensure the safety of both commercial and military aviation aircraft. Nondestructive evaluation (NDE) techniques are integral to this effort. In particular, NDE techniques are used to detect and characterize damage to aircraft and validate models of materials through iterative testing. The costs associated with the acquisition of major aircraft require a long usage period in order to obtain a good return on investment. Commercial and military aircraft fleets are inspected and maintained to produce a long operational life. However, many NDE techniques are slow, tedious, and costly. Interestingly, the technologies used to inspect aircraft to detect flaws are quite sophisticated, but tools for keeping track of these flaws, their location, and evolution over time are haphazard and inspection-specific, so they are not easily generalized to inspections in general.

Cybernet Systems Corporation proposes to leverage its machine vision technology to help automate portions of the inspection process to greatly reduce the time and cost associated with the inspection task. In this approach, machine vision is used to localize sensor scan information gathered during inspection so that it can be viewed and manipulated in the context of a 3D CAD model of the inspected object. The model helps support the prediction of flaw propagation and structure life. The system allows maintainers to accurately collect information about flaws and accurately integrate them into CAD models. The models can then be leveraged using finite element analysis tools to help predict flaw and material behavior.

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OBJECTIVES

The overall Phase 2 objective is to create a prototype system that is capable of tracking NDE sensors and the parts under test to identify the actual location of detected defects and integrating these defects into the CAD model of the inspected part. Cybernet Systems will be performing a number of tasks to meet this objective, but the most important tasks include the following:

- ♦ Quantify the formal requirements for the prototype system.
- ♦ Extend the Phase 1 part tracking system to be more accommodating to changes in light or other factors.
- ♦ Extend the Phase 1 sensor tracking system to be more robust.
- ♦ Incorporate flaw mapping software that supports tagging CAD files with defect locations.
- ♦ Evaluate system performance.

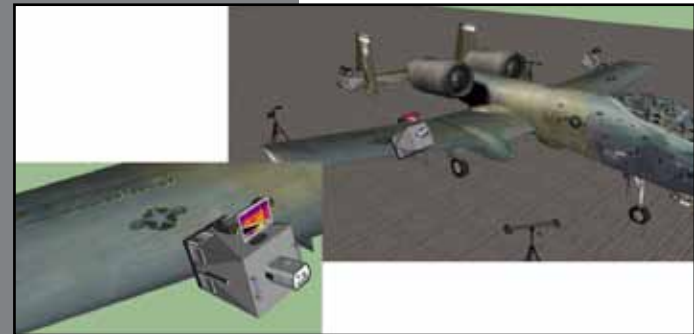
APPLICATIONS

NASA Applications

- ♦ Inspection of large structures on aging aircraft
- ♦ Inspection of large structures on spacecraft
- ♦ Long-term trend analysis of flaw data

Non-NASA Applications

- ♦ Inspection of military aircraft fleets
- ♦ Inspection of commercial aircraft fleets
- ♦ Inspection of helicopter systems



DARWIN-HC: A Tool To Predict Hot Corrosion of Nickel-Based Turbine Disks

INNOVATION

Hot corrosion of turbine engine components has been studied for many years. The underlying mechanisms of Type I hot corrosion and Type II hot corrosion are increasingly well-understood. Modern turbine engine designs that seek to achieve better fuel efficiency in part by increasing turbine inlet temperatures are strong candidates for nickel-based superalloy turbine disk materials. As disk temperatures approach 700 °C, designers must consider the likelihood and effects of Type II corrosion, which is typically characterized by localized corrosion pitting caused by melting of sulfur-containing salts. Type II hot corrosion pits have been shown to decrease the fatigue resistance of superalloys due to initiation of fatigue cracks at hot corrosion pits. However, the rigorous analytical models and tools needed by turbine engine designers to predict Type II corrosion effects are not currently available.

The overall objective of this research program is to develop DARWIN-HC—a probabilistic Type II hot corrosion, fatigue cracking, and fatigue life prediction software tool for nickel-based superalloy turbine disks. The Phase 1 research was based on data provided by both NASA and the research team. The key Phase 1 innovations included enhanced probabilistic models that are explicitly parameterized by the relevant environmental and material variables. The models are a significant step towards modeling the spatial and temporal evolutions of corrosion pits, setting the stage for the development of fatigue life prediction capability. Whereas the existing DARWIN software contains probabilistic models of hard alpha anomalies in titanium disk materials, DARWIN-HC will feature the probabilistic models of defect distributions due to Type II hot corrosion, which can lead to fatigue crack initiation. In Phase 2, the team will create a functional DARWIN-HC prototype software application for evaluation by NASA and industry.

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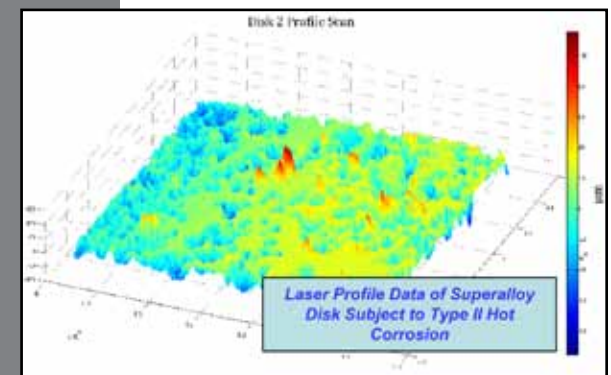
Proposal # 09-2 A1.03-8806

OBJECTIVES

- ◆ Develop a new tool, based on the DARWIN platform, to predict the effects of Type II hot corrosion of nickel-based superalloy turbine disks
- ◆ Generate hot corrosion data sets
- ◆ Design enhanced parameterized probabilistic models of corrosion pitting and crack initiation
- ◆ Develop hot corrosion module for the DARWIN platform
- ◆ Modify the DARWIN platform to incorporate HC functionality
- ◆ Conduct industry review and usability study

APPLICATIONS

- ◆ Highly efficient turbine engine designs for military and civil aircraft produce disk operating temperatures hospitable to Type II corrosion
- ◆ The DARWIN platform is sponsored by the FAA, received an R&D 100 Award, and is widely used for modeling defects, crack growth, and failure probability in titanium disks
- ◆ The DARWIN-HC platform is a logical and important extension to the DARWIN platform



Molecular Air Data Clear Air Turbulence Sensor: MADCAT

INNOVATION

Clear air turbulence (CAT), often referred to as a group of air pockets, is attributed to Kelvin-Helmholtz instabilities at altitudes usually above 18,000 ft, often without visual cues (clouds, etc.), making it difficult to avoid. The vortices produced when atmospheric waves “break” can have diameters of 900 to 1,200 ft and tangential velocities of 70 to 80 ft/sec. CAT is dangerous to aircraft, as recently demonstrated by conditions that affected United Flight 967 from Washington-Dulles to Los Angeles on July 21, 2010. The flight encountered severe in-flight turbulence and landed in Denver with more than 30 injured passengers, 21 of which required a hospital visit. Many other turbulence incidents have caused injuries or deaths to passengers and crew. Another recently highlighted hazard is the inadequacy of current airspeed sensors on commercial aircraft. Federal investigators have reported that on at least a dozen recent flights by U.S. jetliners, malfunctioning equipment made it impossible for pilots to know how fast they were flying. A similar issue is believed to have played a role in the June 2009 crash of Air France 447, which killed all 228 people onboard.

Michigan Aerospace Corporation (MAC) proposes the Molecular Air Data and Clear Air Turbulence (MADCAT) system, which will be capable of providing not only a look-ahead capability to predict clear air turbulence but also a full air data solution (airspeed, angle of attack, angle of sideslip, pressure, and temperature). The technology has already been demonstrated in-flight, confirming its ability to measure these air-data parameters. In addition, ground units based upon the same core technology have demonstrated the ability to detect atmospheric turbulence. MAC's direct-detection UV LIDAR technology uses molecular backscatter and does not require airborne particles and/or vapor to be suspended in the air, as do other proposed solutions based on radar and LIDAR. This Phase 2 project will result in a laboratory test model of MADCAT and a plan for subsequent airborne testing.

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Proposal # 09-2 A1.04-9447

OBJECTIVES

Technical Objectives

- ♦ Establish final MADCAT technical specifications
- ♦ Fabricate and test an engineering model of MADCAT
- ♦ Recommend a final design for testing on an airborne platform

Work Plan

- ♦ Finalize MADCAT design specifications
- ♦ Design and fabricate a MADCAT engineering model
- ♦ Further develop algorithms necessary to process MADCAT data
- ♦ Design an engineering model test program
- ♦ Run engineering model tests
- ♦ Draw up recommendations for a MADCAT prototype design suitable for airborne testing

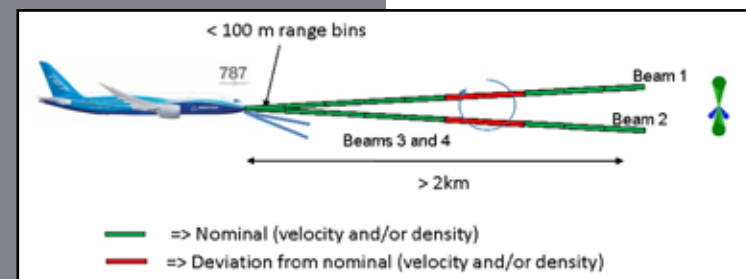
APPLICATIONS

NASA Applications

Turbulence detection for both warning and research purposes (optical air data system capability)

Non-NASA Applications

Commercial and military aircraft turbulence warning with optical air data system capability (turbulence warning and wind mapping for ground applications, such as for wind farms, military artillery, and other fire-control activities)



Simulator Evaluation of a Joint Human/Automated Upset Recovery System and Training Aid

INNOVATION

Loss of control is a significant cause of aviation accidents attributed to a large percentage of fatalities in the commercial aviation sector. Barron Associates, Inc. (BAI) has developed a system for unmanned aerial vehicles that autonomously executes recovery strategies to rapidly restore nominal flight. During Phase 1, BAI sought to extend this system to manned vehicles by developing a joint human-automated (H/A) system. The goal of this system is to assist the crew during the recovery process by conveying information about recovery procedures in an intuitive and unobtrusive manner. BAI developed crew-specific extensions to the automated system at the architecture and the interface level. The architecture defines what information is delivered to the crew. The interface defines how this information is presented to the crew. Metrics were defined to measure the quality of the recovery and crew experience.

Phase 1 pilot-in-the-loop experiments have shown the potential for significant performance gains and workload reduction if the joint H/A recovery system is used to guide the pilot through the recovery process. Phase 1 experiments were limited in scope. During Phase 2, BAI plans to build upon results by demonstrating that gains become even more pronounced in a realistic cockpit environment. This will require migrating to a higher-quality simulator and more accurately simulating crew duties. The team will target airline transport pilots (ATPs) during Phase 2 and expand the subject population so that the benefit of the system can be explicitly quantified. While integration into the cockpit is the ultimate goal for this system, BAI believes that the joint H/A recovery system can be of immediate use as a training aid. As part of the experimental buildup, BAI also would like to show that the use of the joint H/A recovery system during training translates into improved pilot recoveries when the system is not active.

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Proposal # 09-2 A1.05-8718

OBJECTIVES

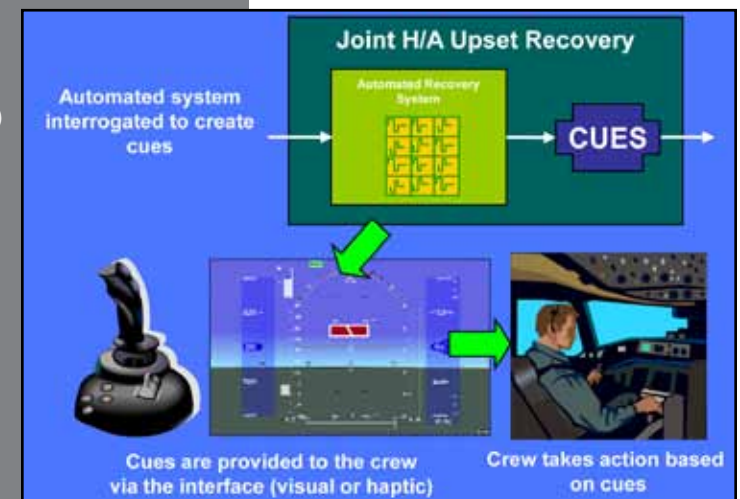
- ♦ Quantify performance gains of H/A recovery system
- ♦ Assess use of H/A recovery system as a training aid

Technical Work Tasks

- ♦ Refine and implement architecture extensions
- ♦ Refine and implement interface extensions
- ♦ Develop training aid
- ♦ Perform ATP evaluation in flight simulator

APPLICATIONS

- ♦ Civil and military aviation safety
- ♦ Remotely Piloted Vehicles (RPVs)
- ♦ Space exploration
- ♦ Any piloted vehicle



Integrated Design and Analysis Environment for Safety Critical Human-Automation Systems

INNOVATION

Numerous advances have been made in recent years in the areas of flight deck design, aircraft modeling, resilient control, and vehicle health management. The combination of these complementary technologies promises to revolutionize aircraft systems and operations safety in the decades ahead. However, the task of safely integrating these technologies is becoming increasingly difficult as their level of complexity, degree of automation, and demands from their operational environment grow. The Next Generation Air Transport System (NextGen), while providing significant benefits in terms of increased capacity and safety, will exacerbate this situation due to the large numbers of new and existing systems that will be required to interoperate.

The multidisciplinary nature of these systems is a significant factor that makes analyzing their safety characteristics extremely difficult. While many development tools exist to conduct deep analyses within individual disciplines, there is a lack of tools available for deep analysis of complex multidisciplinary designs. The proposed research seeks to create a new class of development tool that will allow designers of complex systems within systems to explore the dynamic interactions between system components and uncover systemic vulnerabilities, precursory conditions, and likely outcomes.

The Phase 1 project generated an initial implementation of the software package idea, an integrated design and analysis environment that could be used to model complex interdependencies between flight deck operations, flight deck controls and displays, and the underlying physical components of the aircraft. The proposed Phase 2 effort will mature this software and expand its capabilities, resulting in a flexible, standards-compliant tool that is ready for beta testing and subsequent commercialization. It will focus on enhancements that support cross-disciplinary modeling and analysis of safety-critical human-automation systems.

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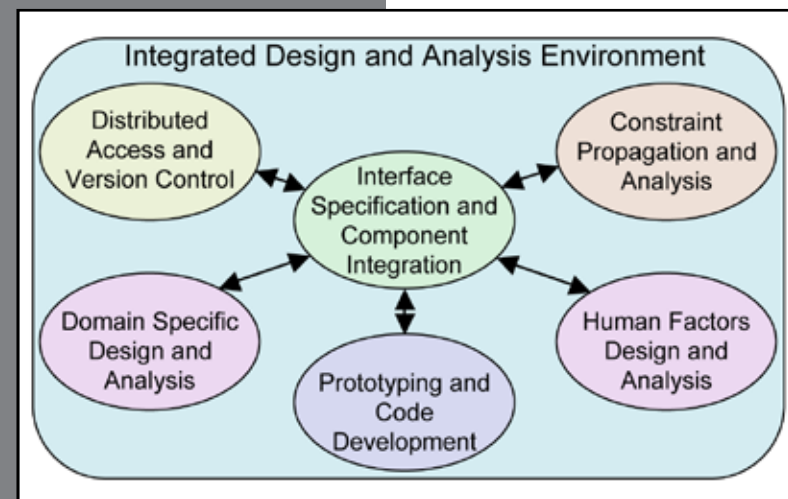
Proposal # 09-2 A1.06-8711

OBJECTIVES

- ♦ Unify multiple facets of component design, propagating through subsystem hierarchies and signal paths and across disciplines and tool boundaries
- ♦ Unambiguously define constraints among property relationships that must hold in order to remain valid
- ♦ Explore dynamic interactions between components
- ♦ Support validation and verification processes

APPLICATIONS

- ♦ Flight deck design and analysis
- ♦ Aviation safety and NextGen
- ♦ Space systems and military aviation
- ♦ UAV, UGV, and UUV operator interfaces
- ♦ Medical systems and health care
- ♦ Other safety critical systems



Real-Time Methods for Adaptive Suppression of Adverse Aeroservoelastic Dynamics

INNOVATION

Adverse aeroservoelastic (ASE) interaction is a problem on aircraft of all types, causing repeated loading, enhanced fatigue, undesirable oscillations, and catastrophic flutter. Traditionally, to suppress adverse ASE interaction, notch and/or roll off filters are used in the primary flight control system architecture. This solution has pitfalls: rigid body performance is degraded due to resulting phase penalty and it is not robust to off-nominal behavior. In Phase 1, an approach was developed that is known as Modal Isolation and Damping for Adaptive Aeroservoelastic Suppression (MIDAAS). This adaptive technique determines an optimal blend of multiple outputs that effectively isolates a problematic lightly damped mode and simultaneously determines an optimal blend of multiple inputs to suppress the problematic mode via feedback. Adverse effects on aircraft rigid body performance are minimized, resulting in virtually no phase penalty.

MIDAAS was successfully validated against ASE F/A-18C aircraft models with varying stores configurations. In the proposed Phase 2 program, a robust real-time adaptive ASE suppression solution will be developed with a buildup approach that includes further MIDAAS enhancements and extensive validation studies utilizing a high-fidelity CFD-based aeroelastic model of the NASA X-53 aircraft. Extensive validation studies utilizing real-time pilot-in-the-loop simulation capability will be included.

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Proposal # 09-2 A1.07-9237

OBJECTIVES

The main objective is the development and application of a real-time flight-ready adaptive control algorithm for ASE suppression. A high-fidelity fighter research aircraft model will be used for development, application, and validation via high-fidelity nonlinear simulation as well as fixed and motion base piloted simulation. Other objectives include:

- ♦ Enhancement of the MIDAAS algorithm, which includes the further development of a practical system identification approach
- ♦ Development of a database of aeroelastic fighter research aircraft models with varying system parameters (including an interpolation capability based on variable model parameters)
- ♦ Application of the MIDAAS controller for ASE suppression to the fighter model and validation of efficacy via high-fidelity nonlinear simulation with large parameter variance
- ♦ Validation of MIDAAS efficacy via fixed and motion base piloted simulation

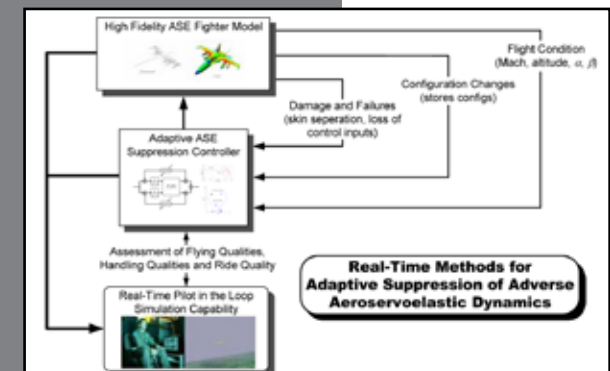
APPLICATIONS

NASA Applications

The developed adaptive ASE suppression algorithms and subsequent real-time piloted validation simulations will greatly benefit NASA flight test programs by providing a solution to reject adverse ASE dynamics that is robust to off-nominal system variations including flight condition changes, configuration changes as well as damage and failure scenarios. Potential NASA benefits other than aeronautic programs include adverse dynamic suppression in both manned and unmanned spacecraft systems.

Non-NASA Applications

Other government flight test centers and commercial aircraft manufacturers, both manned and unmanned, will benefit from the adaptive ASE algorithms and subsequent real-time simulated flight test verification by providing a validated solution that is robust to off-nominal system variation.



Aircraft Engine Life-Consumption Monitoring for Real-Time Reliability Determination

INNOVATION

The object of this research is to develop an in-service life-monitor system for the prediction of the remaining component and system life of aircraft engines. The embedded system will monitor engine thrust, exhaust gas temperature, engine efficiency, speed, and the time of operation of the engine in flight. Based upon this data, the life-estimation analog of the system will calculate the remaining life of each component in the engine and combine these into a prediction of the remaining life for the engine. The calculations will be based on the statistical life distribution of the engine components and their relationship to load, speed, temperature, and time. The monitoring device will be built for use with an operational aircraft engine.

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OBJECTIVES

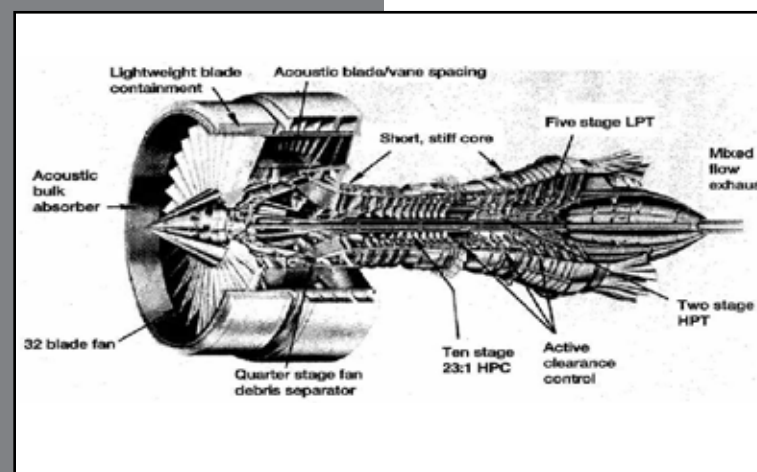
The objective of this research is to develop a real-time aircraft engine life-monitor system that will predict the remaining component and system life for aircraft engines. The embedded system will monitor engine parameters such as thrust, exhaust gas temperature, engine efficiency, speed, and flight time, and calculate in real time the remaining life and reliability of the system based on the statistical life distribution of the engine components.

The project will be accomplished through a series of steps that involve acquiring profiles of aircraft system engines, developing a complete embedded hardware/software system architecture, verifying the system design in simulation, and finally integrating the life monitor into a commercial aircraft.

APPLICATIONS

The NASA Aviation Safety program is pursuing a goal to increase flight safety of commercial aircraft. By addressing deficiencies in analytical life prediction models of aircraft engines, NASA can achieve this goal through a better understanding of the service life of aircraft engines.

This effort will also provide the commercial aerospace industry with improved safety, reliability, and value of commercial aircraft by extending the life of engines and eliminating the high costs associated with unscheduled maintenance procedures due to unexpected failures.



Smart Adaptive Flight Effective Cue (SAFE-Cue)

INNOVATION

To enhance aviation safety, numerous adaptive control techniques have been developed to maintain aircraft stability and performance in the presence of failures or damage. Flight evaluations of various adaptive controllers conducted by NASA and others have shown great promise. In some cases, unfavorable pilot-vehicle interactions including pilot-induced oscillations have occurred. Susceptibility to such interactions is more likely when the pilot interacts with a highly nonlinear vehicle that may no longer have predictable response characteristics. To alleviate these unfavorable interactions, Systems Technology, Inc. proposes the Smart Adaptive Flight Effective Cue (SAFE-Cue). This innovative system provides force feedback to the pilot via an active control inceptor with corresponding command path gain adjustments.

The SAFE-Cue alerts the pilot that the adaptive control system is active, provides guidance via force feedback cues, and attenuates commands, thus ensuring pilot-vehicle system stability and performance in the presence of damage or failures. Phase 2 will build upon a successful Phase 1 demonstration wherein SAFE-Cue configurations eliminated pilot-vehicle system oscillation tendencies, allowing the evaluation pilots to focus on the task rather than on maintaining control. In this proposed program, a prototype SAFE-Cue will be developed and evaluated with exemplar adaptive controllers using the Calspan Learjet In-Flight Simulator.

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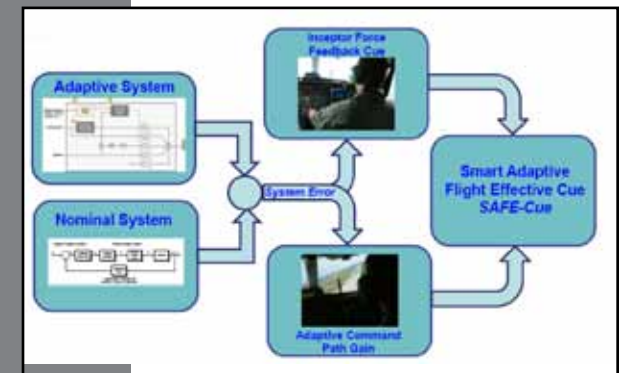
OBJECTIVES

- ♦ Develop a series of advanced failure/damage scenarios with the NASA Generic Transport Model that will be used to assess the capabilities of the SAFE-Cue system, including cross-axis coupling
- ♦ Integrate several representative adaptive controllers to address the selected failure/damage scenarios
- ♦ Develop prototype SAFE-Cue mechanizations that consider several flight conditions and pitch and roll axis implementations including cross-coupling
- ♦ Conduct piloted simulations to down select those failure/damage scenarios that will be used as part of the in-flight evaluations
- ♦ Integrate selected models, adaptive controllers, and SAFE-Cue mechanizations with the Calspan Learjet in-flight simulator
- ♦ Conduct formal flight test evaluations using the Calspan Learjet and selected damage/failure scenarios

APPLICATIONS

The SAFE-Cue approach proposed herein directly addresses a concern of the Integrated Resilient Aircraft Control topic under NASA's Aviation Safety Program to prevent pilot-vehicle system loss of control in the presence of an active adaptive control system.

- ♦ Aircraft with modern fly-by-wire flight control systems that can also support the use of adaptive control systems
- ♦ Commercial transport aircraft fleet where it can add a significantly increased level of safety at a reasonable incremental cost
- ♦ Extreme military operational environments, including use of the F-35 Joint Strike Fighter and CH-53K lift cargo helicopter, which feature active control inceptors



In-Flight and Pre-Flight Detection of Pitot Tube Anomalies

INNOVATION

The health and integrity of aircraft sensors play a critical role in aviation safety. Unfortunately, inaccurate or false readings from sensors can lead to improper decision-making, resulting in serious and sometimes fatal consequences. The research performed in Phase 1 demonstrated the feasibility of using advanced data analysis techniques to identify anomalies in pitot tubes resulting from blockage such as icing, moisture, or foreign objects. The core technology used in this project is referred to as “noise analysis” since it relates a sensor’s response time to the dynamic component (noise) found in the signal from these same sensors. This analysis technique uses existing electrical signals from pitot tube sensors that result from measured processes during in-flight conditions and/or induced signals in pre-flight conditions to detect anomalies in the sensor readings.

Analysis and Measurement Services Corporation has routinely used this technology to determine the health of pressure transmitters in nuclear power plants. The application of this technology for the detection of aircraft anomalies is innovative in that instead of determining the health of process monitoring at a steady-state condition, this technology will be used to quickly inform the pilot when an air speed indication becomes faulty under any flight condition as well as during pre-flight preparation.

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Proposal # 09-2 A1.10-8957

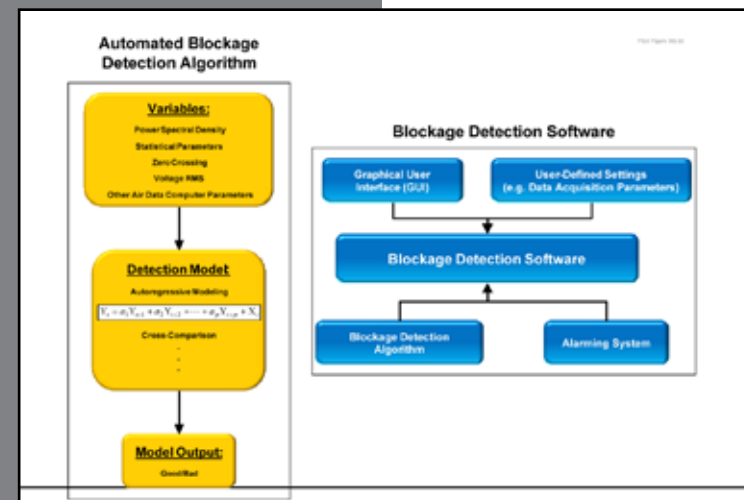
OBJECTIVES

- ♦ Research and acquire existing air data systems and evaluate them for compatibility with the proposed signal analysis techniques
- ♦ Complete laboratory experiments to identify the signal analysis techniques that best distinguish pitot tube blockage
- ♦ Develop and optimize the in-flight blockage detection algorithm and software
- ♦ Develop and build in-flight and pre-flight blockage detection prototype systems
- ♦ Demonstrate and validate a prototype blockage detection system through in-flight testing

APPLICATIONS

The general target market for this product is in the commercial and private aircraft sectors, although NASA and other governmental/military agencies would equally

benefit from this technology. As all aircraft rely on the accurate and reliable performance of pitot/static systems, improving the detection of inaccurate indications would increase the safety to passengers/crew, reduce the potential for accidents, and lead to other advances in aviation technology. Depending on the end product, it is conceivable that this new technology could be used not only for new aircraft, but for also existing aircraft with only minor modifications.



Physical Modeling for Anomaly Diagnostics and Prognostics

INNOVATION

Ridgetop has developed an innovative, model-driven anomaly diagnostic and fault characterization system for electromechanical actuator (EMA) systems to mitigate catastrophic failures. In addition, the company has developed a MIL-STD-1553 bus monitor and controller that simulates the aircraft data bus, reads the environmental (i.e., altitude) and operational (i.e., response of system) data of a system, determines if a fault is manifesting, and if true, determines the symptoms and the root cause. Once an anomaly is detected, the Model-based Avionic Prognostic Reasoner (MAPR) solves a user-outlined state-space model, symbolically using a Gauss-Newton optimization method and the information from the MIL-STD-1553 bus. This algorithm outputs a list of best fitting parameters that match the command to the actual performance. Rules are programmed based on results from principal component analysis. The rules determine both the fault mode and its severity and can distinguish three modes: mechanical jam failure, MOSFET failure, and healthy.

Real-time processing will allow for critical evolutions in flight safety and provide a game-changing approach to condition-based maintenance. Once deployed, flight safety can be improved by allowing the on-board flight computers to read from the MAPR and update the control envelope based on its evaluations, reducing damage propagation and increasing operational safety.

In Phase 2, Ridgetop will develop a functioning ground-based prototype of the technology to show the efficacy of the method. A ground-based version of the tool is the best candidate for development to ease adoption by testing in a low-risk environment. This tool will be demonstrated at the end of Phase 2. The MAPR concept is also applicable to any system with a state-space representation, but at this point it has been developed with EMAs in mind. The MAPR prototype is at TRL 5 and will reach a TRL 7 by the end of Phase 2.

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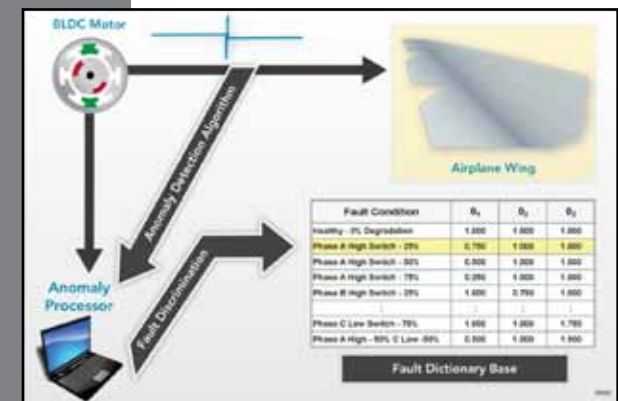
Proposal # 09-2 A1.12-9941

OBJECTIVES

- ♦ Evaluate MIL-STD-1553 and ARINC 429/629 communication protocols to build a representative testbed
- ♦ Classify the faults that can be detected with each protocol
- ♦ Develop a mathematical model of a representative aircraft subsystem (e.g., electromechanical actuator) tailored to accommodate the communication protocol's limitations
- ♦ Characterize performance of this model-based method
- ♦ Validate that this method will effectively communicate using existing infrastructure and protocols

APPLICATIONS

- ♦ NASA/Ames Research Center Advanced Diagnostics and Prognostics Testbed (ADAPT)
- ♦ NASA EMA and power systems
- ♦ Department of Defense applications utilizing MIL-STD-1553
- ♦ Commercial aerospace using ARINC 429 and ARINC 629
- ♦ Industrial Factory Automation applications using standard bus structures



A Software-Assurance Design Approach for NextGen Enabling Technologies

INNOVATION

The U.S. air transportation system is not performing adequately, even as aircraft operations increase. To address this problem, the Federal Aviation Administration and the Joint Planning and Development Office are developing the Next Generation Air Transportation System (NextGen). NextGen will enable critical advances to the current management of the National Airspace (NAS). The technologies that comprise NextGen offer the possibility of compelling new systems of systems that, if properly designed, will not only enhance the capabilities of the NAS but also improve its safety. At the same time, these fundamental changes bring with them implications for safety and security. In order to address these concerns, new techniques for the certification of software systems will be required to ensure that certification costs do not limit the safety innovations offered by NextGen advances. In Phase 1, Barron Associates investigated the integration of ADS-B and TCAS as a representative NextGen system of systems and investigated the application of the system safety case to the system.

In Phase 2, Barron will develop a new collision-avoidance system and conduct an empirical study of the system safety case compared to DO-178B compliance as a certification approach. Throughout the development of the new collision-avoidance system, evidence in support of DO-178B compliance as well as in support of the safety case will be gathered. The team will answer key research questions that center on the use of the system safety case as an alternative means for airworthiness certification.

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Proposal # 09-2 A1.14-8756

OBJECTIVES

- ♦ Build a collision-avoidance system with ADS-B surveillance
- ♦ Conduct safety engineering on the collision-avoidance system
- ♦ Gather DO-178B and safety-case evidence
- ♦ Conduct empirical study

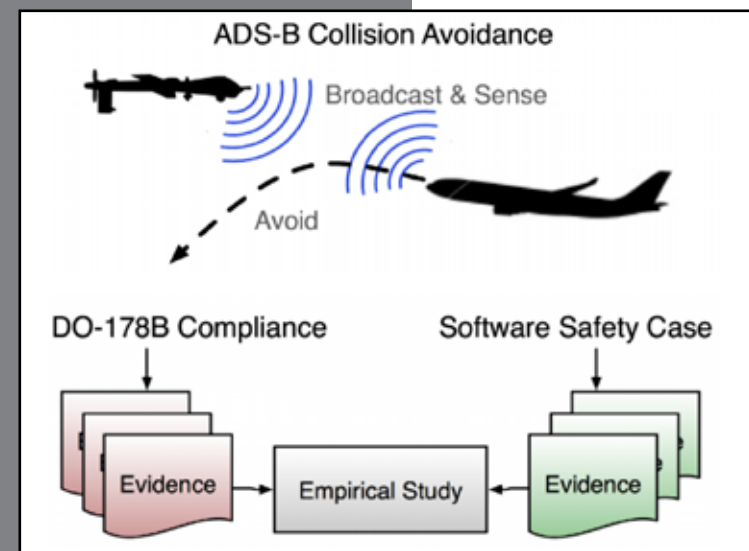
APPLICATIONS

NASA Applications

- ♦ TCAS enhancement/replacement
- ♦ NextGen avionics software

Non-NASA Applications

- ♦ Unmanned systems
- ♦ Robotic and industrial process devices
- ♦ Nuclear power plant/propulsion control



FUNDAMENTAL AERONAUTICS PROGRAM

The Fundamental Aeronautics Program (FAP) is dedicated to the mastery of the principles of flight in any atmosphere at any speed. Physics-based, multidisciplinary design, analysis, and optimization tools are being developed that will make it possible to evaluate radically new vehicle designs and to assess the potential effects of innovative technologies and concepts on overall vehicle performance.

FAP is organized into four projects:

- Subsonic Fixed Wing Project addresses challenges that future aircraft need to be quieter and cleaner to meet stringent noise and emissions regulations
- Subsonic Rotary Wing Project focuses on technical barriers that constrain rotorcraft from reaching widespread use in civil aviation
- Supersonics Project conducts research to address the efficiency, environmental, and performance barriers to practical supersonic cruise vehicles
- Hypersonics Project tackles fundamental research issues required to make hypersonic flight and reentry feasible



Shape Memory Alloy-Based Periodic Cellular Structures

INNOVATION

This SBIR Phase 2 effort will continue to develop and demonstrate an innovative shape memory alloy (SMA) periodic cellular structural technology. Periodic cellular structures (PCSs) will be designed and tailored to determine whether additional shape memory performance benefits can be derived from the underlying macro-structure when fabricated from SMAs. These structures will be manufactured using an advanced reactive metal casting technology that will allow complex-shaped, integral bulk structures to be fabricated with the requisite composition-microstructure properties needed for shape memory performance. Casting also offers a relatively low-cost approach for fabricating near net-shape components. The fabricated SMA structures will be characterized for resulting microstructure properties in order to determine how to best design PCSs to better exploit SMAs for use in aerospace applications.

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Proposal # 09-2 A2.01-8248

OBJECTIVES

Understand how to best design, exploit, and maximize the performance benefits of cast SMAs in the form of PCSs and solids. A key goal is to examine how well PCSs of various designs can perform in recovery compared with what would be expected for a solid of the same alloy in order to quantify any structural benefits that may result.

Work Plan

- ◆ Devise and standardize the processing methods that best optimize the cast SMA microstructure properties for shape memory behavior.
- ◆ Design new PCS concepts that will contribute to unique shape memory behavior and response rate to achieve target performance.
- ◆ Examine the interrelationship between starting material, shape memory properties, and overall periodic cellular structural (mechanical) behavior for solids and prototype PCSs.

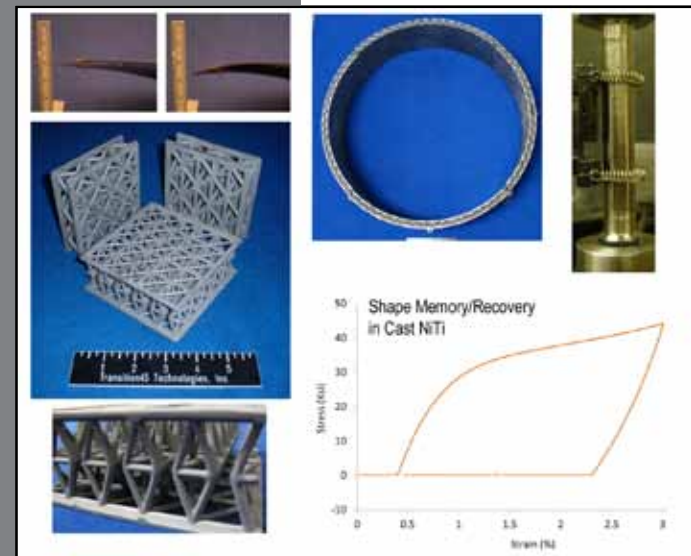
APPLICATIONS

NASA Applications

- ◆ Engine and airframe components, including actuators, flexible wings, nozzles, and ballistic impact resistant structures

Non-NASA Applications

- ◆ Building and bridge structural components (hinges, brackets) that resist explosions (e.g., terrorist bombs, IEDs) and earthquakes
- ◆ Armor, vibrational and acoustic isolation, automobile spoilers, biomedical implants, fire safety, HVAC control, flow control



Interfacial Design of Composite Ablative Materials

INNOVATION

This project proposes the development of a computational software package to provide NASA with advanced materials development capabilities for existing and new ablative materials used in the next generation thermal protection systems (TPS) of space vehicles. This materials development software package (MDSAM) can be used to optimize properties (high strength and low thermal conductivity) for virgin material and the char that forms during operating conditions. It will provide atomistic-level information on char evolution and the degradation of thermo-mechanical properties. The proposed MDSAM will consist of the following modules:

- 1) an experimentally validated, atomistic-level simulation engine capable of predicting the role of interfacial structure on the resin-to-carbon process
- 2) atomistically-informed continuum-level thermo-mechanical performance analyzer for composite ablative materials subjected to transient pyrolytic conditions

The underlying methodology and the software package will be transitioned to NASA scientists working on ablative materials development. In addition to developing a computational software package, Advanced Cooling Technologies will address open, unsolved problems in the literature to support NASA's ablative materials development requirements. In the course of developing this methodology, the company will produce significant scientific results on pyrolysis and materials properties that will be important to NASA.

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Proposal 3 09-2 A2.01-8833

OBJECTIVES

Technical Objectives

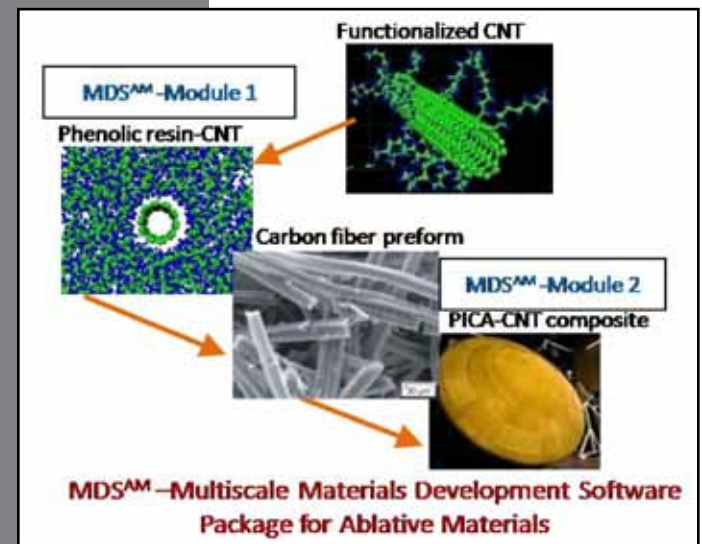
The MDSAM software package will be developed to optimize thermo-mechanical properties for both the virgin material and char.

Work Plan:

- ♦ Module 1—Accelerated materials development methodology development
- ♦ Module 2—Multiscale-multiphysics simulator based on MDS-C experimental validation

APPLICATIONS

The developed computational software package will address open, unsolved problems in the literature to support NASA's ablative materials development requirements. The software package will be capable of studying a wide range of existing ablative materials and designing novel ablative materials. In the course of developing this methodology, significant scientific results will be produced on pyrolysis and materials properties that are important to NASA. This software package technology can be applied to study high temperature oxidation and pyrolysis processes in materials that are of interest to the chemical, petrochemical, aerospace, and defense industries.



SiC Matrix Composites for High Temperature Hypersonic Vehicle Applications

INNOVATION

Durable high-temperature materials are required for reusable hypersonic structural thermal protection systems. In particular, temperatures exceeding 2,700 °F, and approaching 3,000 °F, are targeted for capable structural materials that can survive stresses on the order of 10 ksi (70 MPa) for at least 100 hours in an oxidizing environment. Such materials have been identified as an enabling material for future hypersonic vehicles. As this application is structural, a strong degree of damage tolerance is desired, and thus ceramic matrix composites are the primary choice due to the desire for reduced weight, high-temperature strength, and oxidation resistance. Silicon carbide fiber-reinforced silicon carbide matrix (SiC/SiC) composites are believed to be the most suitable solution due to meeting the requirements with the limitations of creep at the highest temperatures/loads, and oxidative attack at stresses that exceed the materials proportional limit. The proposed effort will define the temperature-stress limit of SiC/SiC composites and examine methods to further extend this limit.

OBJECTIVES

This proposed effort will continue development of a 2,700 °F+ SiC/SiC composite with an idealized goal to demonstrate a 100 hour life at 10 ksi and 3,000 °F. The Phase 2 effort intends to optimize creep performance by manipulating the fiber architecture and post-conditioning of the composites. Extensive creep testing is planned to provide an understanding of the fundamental limitations of these SiC/SiC composites at these extreme temperatures. A preliminary database of mechanical and thermal properties will be generated for the SiC/SiC composites. A design activity to incorporate SiC/SiC composites into a structural thermal protection system will be conducted and a unit cell element will be thermally evaluated.

APPLICATIONS

A structural TPS produced with an outer wall of 2,700 °F+ SiC/SiC with an inner wall insulated from the high temperatures so that ideally the inner wall can be produced from a much lower temperature material (e.g., polymeric composite). Such a structurally integrated thermal protection system has a higher structural efficiency, and is potentially lower maintenance due to the durable nature of SiC/SiC composites. Applications for SiC/SiC TPSs include advanced air breathing combined-cycle propulsion systems and control surfaces for reusable hypervelocity and exo/transatmospheric aerospace vehicles. Other viable applications for >2,700 °F SiC/SiC include future aeroengines. SiC/SiC composites are currently being developed for both military and commercial aircraft engines, as significant efficiencies can be gained by operating at higher temperatures or with reduced cooling air.

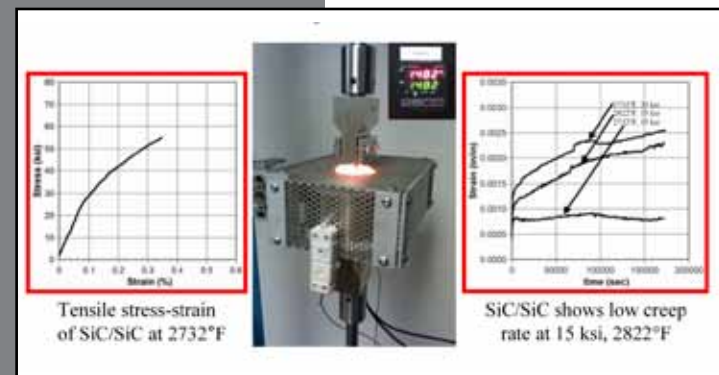
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Proposal # 09-2 A2.01-9131



Lightweight, Efficient Power Converters for Advanced Turboelectric Aircraft Propulsion Systems

INNOVATION

NASA is investigating advanced turboelectric aircraft propulsion systems that utilize superconducting motors to drive a number of distributed turbofans. Conventional electric motors are too large and heavy to be practical for this application, where superconducting motors are required. In order to improve maneuverability of the aircraft, variable speed power converters would be required to throttle power to the turbofans. The low operating temperature and the need for lightweight components that place a minimum of additional heat load on the refrigeration system open the possibility of incorporating an extremely efficient cryogenic power conversion technology. This Phase 2 program will develop critical components required to meet NASA's size, weight, and performance goals.

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Proposal # 09-2 A2.01-9471

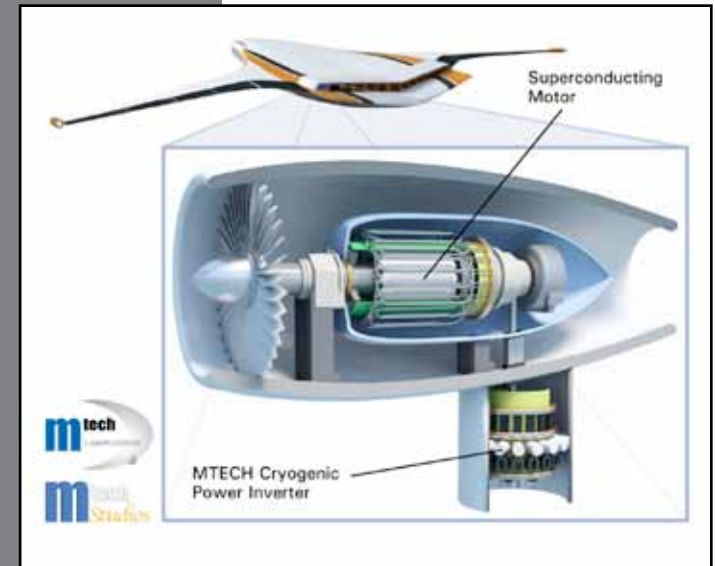
OBJECTIVES

Benefits of cryogenic operation include higher efficiency, increased switching speeds at low temperatures, and reduced diode switching losses. MTECH proposes to develop a critical component necessary to realize the maximum power density, thereby reducing size and weight while maximizing the efficiency. Phase 2 technical objectives are:

- ♦ To design, fabricate, and test a cryogenic multi-chip module, which can be used in a number of applications requiring very high power densities and efficiencies.
- ♦ To design, fabricate, and test a cryogenic half-bridge inverter using these modules. The prototype is expected to demonstrate the potential reduction in size and weight for a given power level, as well as ultra-high efficiency.
- ♦ To present the design and test results to NASA's turboelectric aircraft propulsion group at Glenn.

APPLICATIONS

Apart from superconducting turboelectric drive systems, cryogenic power conversion is a natural fit for a great many NASA applications, including lunar and Mars missions as well as interplanetary and deep-space missions. In short, this technology is useful wherever small size, low weight, and high efficiency are required. Space applications are perhaps the only ones where the natural environment is often cryogenic. Non-NASA markets include the military, the industrial power/utility market, and the medical market. For example, the Navy's all-electric ship program would benefit from this work, especially if superconducting motors and generators are deployed.



SiC-SiC and C-SiC Honeycomb for Advanced Flight Structures

INNOVATION

The proposed project builds upon the work done in Phase 1 with the development of a C-SiC CMC honeycomb material that was successfully tested for mechanical properties at both ambient and high temperatures. The Phase 2 study expands to include the development of a SiC-SiC honeycomb using the proven infiltration process of the Phase 1 project. In the proposed project, a pre-impregnated SiC will be engineered that can be formed into a honeycomb and then infiltrated with SiC to form a ceramic SiC-SiC honeycomb. The honeycomb will then be tested mechanically at ambient and high temperatures. This testing will include cycling the material to determine property falloff. C-SiC and SiC-SiC will be compared in this study. The thermal characteristics, such as conductivity and emissivity, will also be tested. The integration of such a material into hypersonic and other structures is a key area of the research; therefore, a bonding study is included in the current proposal. Several bonding technologies and processes will be investigated and tested mechanically as well as cycled to determine durability. The goal of the study is to provide a sandwich level technology that can be integrated into hypersonic vehicle structures and acreage.

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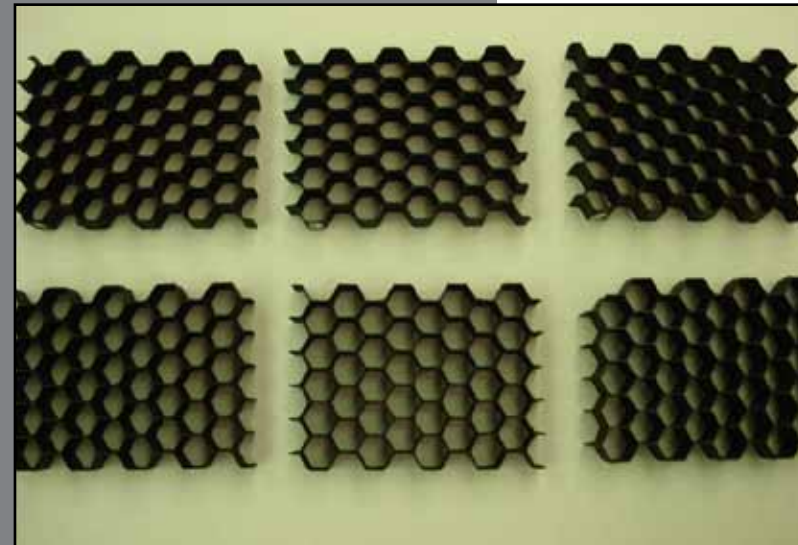
Proposal # 09-2 A2.01-9895

OBJECTIVES

- ♦ Expand research from Phase 1 into SiC-SiC
- ♦ Benchmark two material systems at high temperature
- ♦ Heat cycle both systems to determine mechanical falloff
- ♦ Investigate bonding methodologies and test mechanically

APPLICATIONS

- ♦ Hypersonic flight structural materials
- ♦ General low-weight- and high-heat-resistant core materials



A Compact Safe Cold-Start (CS2) System for Scramjets Using Dilute Triethylaluminum Fuel Mixtures

INNOVATION

This proposal leverages a highly successful Phase 1 feasibility effort to further develop a system that satisfies the cold-start requirements of scramjet engines. The system provides energy-dense, low volume hydrocarbon fuel conditioning based on the hydrolysis reaction of triethylaluminum (TEA) with water. TEA is an organometallic liquid that reacts exothermically with water and burns readily in air. In Phase 1, ACENT Laboratories demonstrated the hydrolysis of TEA in JP (jet propulsion) fuel within an integrated mixing/injection apparatus to heat and vaporize the liquid hydrocarbon fuel prior to injection in a regeneratively cooled scramjet, as well as auto-ignition of the mixture at elevated TEA concentrations.

In Phase 2, ACENT Laboratories proposes to more completely characterize the performance capability of the Phase 1 system using several hydrocarbon fuels to gather data for the design and fabrication of a palletized system. Testing of the palletized system in a direct connect scramjet rig will then be conducted to demonstrate engine ignition capability and to compare the system to other scramjet ignition systems under consideration. Packaging in candidate flight vehicles will be carried out using 3D solid modeling to provide gravimetric and volumetric information and to provide designs for practical integrated, safe storage and dispense arrangements.

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Proposal # 09-2 A2.02-8867

OBJECTIVES

Phase 1 Accomplishments

- ♦ Assessed pyrophoricity of candidate TEA-JP mixtures
- ♦ Developed a thermodynamic model of a mixing/injection system representative of a notional scramjet configuration
- ♦ Built an experimental mixing/injection system, and conducted more than 20 successful tests in June 2010
- ♦ Characterized the performance (e.g., heat release, mixing efficiency, etc.) of the system for various TEA concentrations

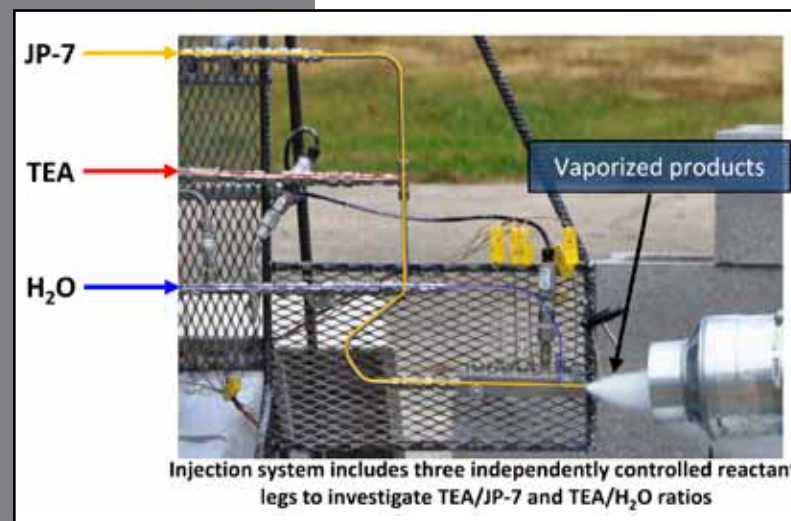
Phase 2 Plans

- ♦ Investigate other hypergolics and fuels including TEA-TEB, JP-10, and RP-1

- ♦ Develop a comprehensive performance map and optimize mixer and injector arrangements
- ♦ Conduct scramjet ignition tests in a direct connect rig
- ♦ Develop 3D packaging models and design practical storage configurations

APPLICATIONS

- ♦ Scramjet ground test engines and flight vehicles (engine start assist, extension of low Mach capability, combustor stabilization, and piloting)
- ♦ High-altitude relight of turbojets



Novel Active Combustion Control Concept for High-Frequency Modulation of Atomized Fuel Flow

INNOVATION

This proposal presents an innovative solution for Active Combustion Control.

Relative to the state of the art, this concept has the ability to provide frequency modulation (greater than 1,000 Hz) in combination with high amplitude modulation (in excess of 30 percent flow) and can be adapted to a large range of fuel injector sizes. Existing state-of-the-art valves tend to have low flow modulation strength or the size of the valves having higher flow modulation seem too large or consume too much electrical power to be practical. The proposed active combustion control valve (ACCV) has high frequency and amplitude modulation, consumes low electrical power, is closely coupled with the fuel injector for modulation strength, and is practical in size and weight.

OBJECTIVES

- ♦ Use analysis and design tools to refine and optimize the design of the ACCV and its associated components including the motor/LVTRX, electronic controller, and proportional solenoid.
- ♦ Finalize the design and generate hardware drawings allowing the ACCV and its associated components to be manufactured.
- ♦ Manufacture the ACCV components and assemble the various components into working prototype units.
- ♦ Perform testing of the ACCV with respect to validating its fuel flow modulation strength and frequency response up to 1,000 Hz.
- ♦ Reduce the test data and determine the effectiveness of the ACCV at modulating fuel flow at 1,000 Hz, validate analysis models, and determine if the ACCV hardware needs modification to overcome issues discovered during the testing.

Work Plan

- ♦ Analysis and Design
- ♦ Generation of Engineering Drawings
- ♦ Hardware Fabrication and Assembly
- ♦ Hardware Testing
- ♦ Reduction and Analysis of Test Data

APPLICATIONS

NASA Applications

NASA has been involved in evaluating the need for such technology and continues to pursue it through SBIR-sponsored and other programs. As a result there are numerous applications that can benefit from this technology, including but not limited to, engines for prime propulsion, auxiliary power, and power generation where higher performance and lower exhaust emissions are desired.

Non-NASA Applications

Large frame power generating gas turbine manufacturers such as Honeywell, United Technologies, Rolls-Royce, General Electric, and Siemens are in need of this technology for their low-emission combustion systems. The market for such a proven device is worldwide.

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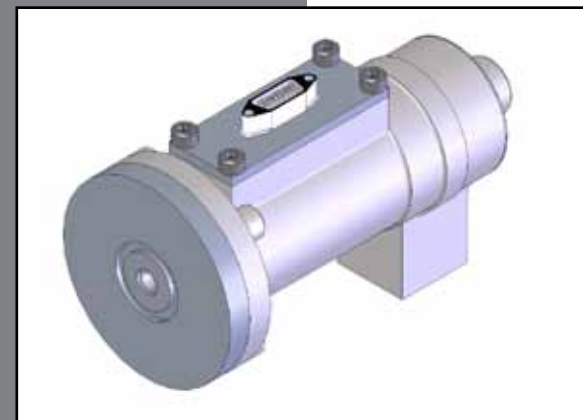
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Proposal # 09-2 A2.02-9291



Ultra High Temperature Capacitive Pressure Sensor

INNOVATION

To improve the working performance, increase efficiency, reduce cost, and track system health status and failure modes of advanced propulsion systems, miniaturized and robust sensing systems for measuring and monitoring physical parameters, such as pressure, would be highly advantageous. Technical challenges for developing reliable sensing systems lie in the extremely harsh working conditions in which the microsensors must operate. In addition to high temperatures and pressures, these conditions include oxidation, corrosion, thermal shock, fatigue, fouling, and abrasive wear. High temperature (300 to 1,350 °C) capacitive pressure sensors are of particular interest due to their inherent suitability for wireless readout schemes. The objective of this proposed work is to develop a capacitive pressure sensor based on SiCN, a new class of high-temperature ceramic materials, which possess excellent mechanical and electric properties at high temperatures (up to 1,600 °C). The Phase 2 effort will include: the development of material formulation and fabrication processes to realize optimized devices, device prototyping, and laboratory scale/relevant environment testing such as that required to achieve a technology readiness level (TRL) of between 5 and 6.

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Proposal # 09-2 A2.02-9410

OBJECTIVES

- ♦ Optimize SiCN formulations to result in materials with optimized dielectric and loss tangent properties.
- ♦ Develop a SiCN device fabrication process to realize air/electrode gap sizes of less than 5 microns.
- ♦ Fabricate improved prototype SiCN sensor devices and perform laboratory scale performance testing.
- ♦ Develop prototype packaging hardware, and (if needed) signal conditioning electronics, integrate prototype sensor devices for internal, laboratory-scale, and performance testing to achieve TRL 4.
- ♦ Based on the results of initial integrated hardware testing, redesign and rebuild prototype hardware for relevant environment testing in NASA and/or original equipment manufacturer (OEM) partner test systems to achieve TRL 5-6.

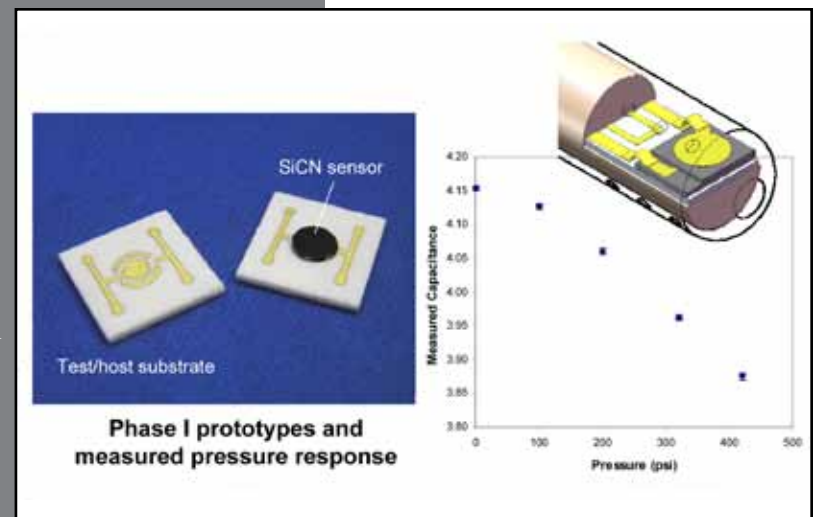
APPLICATIONS

NASA Applications

Planetary exploration/mission to Venus, vehicle health management, propulsion systems, energy generation systems, thermal protection systems

Non-NASA Applications

Commercial and military aerospace propulsion systems/turbine engines, marine propulsion, rail locomotives, land-based power generation turbines, automotive, oil and gas refining, and government and academic laboratories



Adaptive Drainage Slots for Acoustic Noise Attenuation

INNOVATION

Cornerstone Research Group, Inc. (CRG) demonstrated feasibility in the reduction of noise attributed to drainage slots in jet engine acoustic liners. This was accomplished through the development of design rules for optimum slot design and concept development for implementing adaptive material technologies to control slot dimensions. CRG brought this technology to a technology readiness level (TRL) 2 after the Phase 1 effort and will move the technology to a TRL 4 after the Phase 2 effort. The Phase 1 effort provided simulated data for the acoustic designer to start to understand and develop preliminary models on the effects of drainage slots to a liner's acoustic impedance characteristics. This data has provided justification to pursue adaptive solutions that will counteract the adverse effects of drainage slots through adaptive means. In Phase 2, CRG will refine the design, scale up fabrication, demonstrate a full-scale operationally relevant aircraft part, and analyze manufacturing costs as part of a comprehensive technology insertion plan.

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Proposal # 09-2 A2.03-9603

OBJECTIVES

Technical Objectives

- ♦ Develop samples and perform testing
- ♦ Develop adaptive drainage slot concepts
- ♦ Develop and test a prototype acoustic liner
- ♦ Demonstrate the potential for commercial application

Work Plan

- ♦ Fabricate test samples
- ♦ Characterize performance liner samples
- ♦ Develop concepts for adaptive capability
- ♦ Develop concept prototype demonstrator
- ♦ Prepare for Phase 3 transition

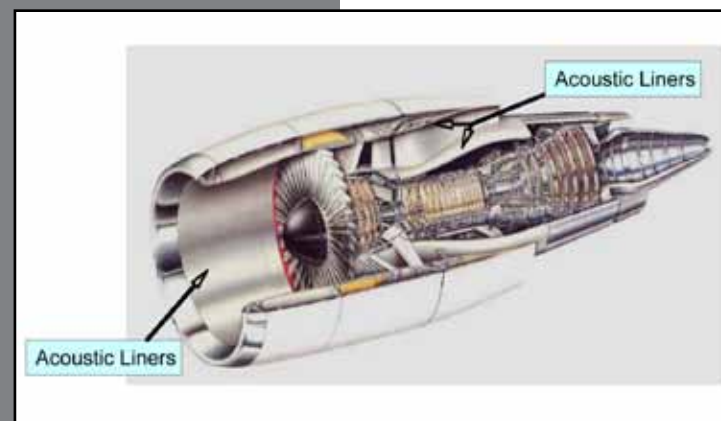
APPLICATIONS

NASA Applications

- ♦ Subsonic and supersonic vehicle systems
- ♦ Fan, jet, turbomachinery, and airframe noise
- ♦ Aerodynamic noise sources

Non-NASA Applications

- ♦ Department of Defense subsonic and supersonic vehicle system
- ♦ Commercial aviation
- ♦ Power generation and maritime power plants



State-of-the-Art, Multi-Fidelity Modeling and Simulation (M&S) Tool for Nonlinear Aeroelasticity

INNOVATION

Research is proposed for the development of a state-of-the-art computational aeroelastic tool. This tool will include various levels of fidelity and the ability to perform computational uncertainty quantification for data-driven risk analysis and certification. A number of novel reduced-order in-time methods will be implemented into the code allowing for efficient and accurate aeroelastic simulation. These methods will enable the exploration of complex physics, point design, and fast generation of “training data” for reduced order spatial aeroelastic models. The various levels of fidelity available in the code for aeroelastic modeling will range from CFD-based (both grid-based and a novel particle-based method) simulation to reduced-order aeroelastic models based upon Volterra series representations and proper orthogonal decomposition (POD).

The application of the proposed innovations spans the range of flight, from high-speed transport vehicles, to small-scale, flapping micro-air vehicles. Anticipated results include

- 1) the further validation and implementation of the proposed novel time-reduced order models into the existing ASTE-P solver framework (which already includes the various level fidelity mentioned above)
- 2) the application of the proposed work to large-scale simulation and comparison with experiment
- 3) the advancement of the state of knowledge for nonlinear problems in aeroelasticity in both the subsonic, low Reynolds number regime and transonic, high Reynolds number regime

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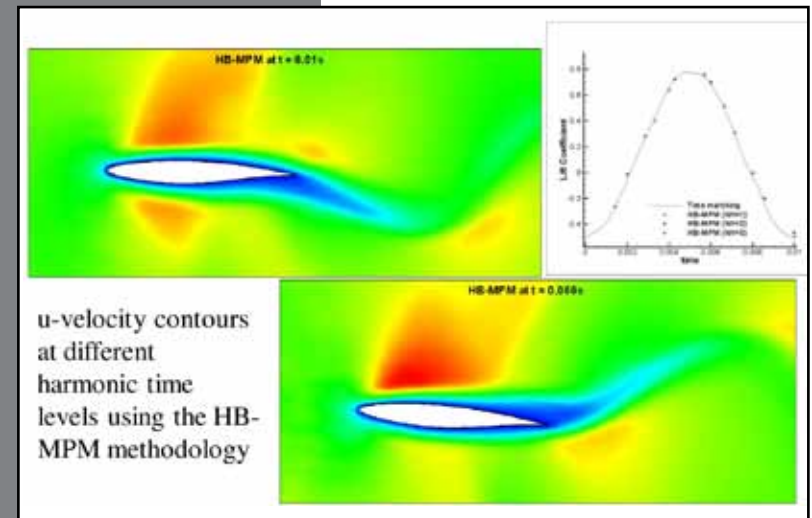
Proposal # 09-2 A2.04-8558

OBJECTIVES

- ♦ Further validate and implement the proposed novel time-reduced order models developed in Phase 1 into the existing ASTE-P solver framework, which already includes the various level fidelity mentioned above
- ♦ Apply the proposed work to large-scale simulation and comparison with experiment, measurements, and other computational results available
- ♦ Advance the state of knowledge for nonlinear problems in aeroelasticity in both the subsonic, low Reynolds number regime, and transonic, high Reynolds number regime

APPLICATIONS

There are a number of applications to subsonic fixed wing, supersonics, and hypersonics projects. Potentially, subsonic rotary wings and CLV projects may also find uses for this technology. Non-NASA government agencies such as the Air Force, Navy, Army, and commercial companies such as Boeing, Bell, Lockheed Martin, and BAE Systems will find applications for the computationally efficient prediction of aeroelastic behaviors such as flutter, LCO, and buffet of aerospace vehicles.



On-Line Flutter Prediction Tool for Wind Tunnel Flutter Testing Using Parameter Varying Estimation Methodology

INNOVATION

ZONA Technology, Inc. (ZONA) proposes to develop an on-line flutter prediction tool to ensure flight safety during flight flutter tests and to prevent damage to the wind tunnel hardware from the structural failure of the flutter model during wind tunnel flutter tests. The prediction tool would employ the parameter varying estimation (PVE) methodology known as the PVE Toolbox. This tool can be applied to rapidly identify parameters, such as modal damping and frequency from test data measured at pre-flutter flight/wind tunnel conditions, then subsequently to assess the flutter boundary of aircraft/wind tunnel models in real time. In the PVE Toolbox, several system identification techniques are employed to consistently estimate the damping/frequency of the physical modes, followed by the implementation of Zimmerman-Weissenburger flutter margin, damping trends extrapolation, linear parameter varying modeling combined with μ -analysis, and thin plate interpolation method for flutter boundary prediction. Seamless integration of the PVE Toolbox into IADS (a real-time flight test data acquisition software system) will significantly improve the on-line flutter prediction capability of the PVE Toolbox.

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Proposal # 09-2 A2.04-9806

OBJECTIVES

The overall objective of the Phase 2 effort is to develop a robust, production-ready, flight test demonstrated PVE Toolbox that can provide flight/wind tunnel test engineers with on-line flutter prediction capability in the control room for decision-making during flight/wind tunnel flutter tests.

Work Plan

The overall objective for Phase 2 will be achieved by three major steps:

1. Enhancing the robustness of the predicted flutter boundary by developing new algorithms
2. Establishing the production readiness of the PVE Toolbox by seamlessly integrating it with IADS
3. Demonstrating the real-time capability by applying the PVE Toolbox to the Multi-utility Aeroelastic Demonstrator (MAD) project, an ongoing AFRL project, to predict the flutter boundary of the Multi-Utility Technology Testbed (MUTT) vehicle in real time during flight tests

APPLICATIONS

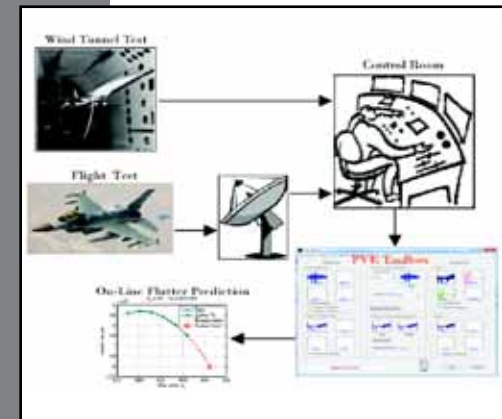
NASA Applications

Comprehensive flutter prediction software is still nonexistent, leading to cautious and expensive wind tunnel testing. ZONA envisions that the proposed Phase 2 research effort will result in a commercial product, called the PVE Toolbox. The PVE Toolbox will be a crucial technology for flight flutter tests of next generation aircraft such as the NASA Hybrid Wind Body Configuration and Quiet Supersonic Transport.

Non-NASA Applications

The potential non-NASA customers for this tool include the R&D arms of the U.S. Air Force, Navy, Army, and the defense industry. It can be readily adapted by a wide class of aerospace vehicles ranging from current to next-generation designs such as:

- ♦ USAF's F-22 and F-35 aircrafts at Edwards AFB
- ♦ USAF's Hilda and/or sensor craft aircrafts
- ♦ USAF's next generation stealth and morphing UAV/UCAV
- ♦ DARPA's new Switchblade Flying Wing Program
- ♦ Micro Air Vehicle (MAV) with enhanced control/maneuver capability



Simulation Tool for Dielectric Barrier Discharge Plasma Actuators at Atmospheric and Sub-Atmospheric Pressures

INNOVATION

Traditional approaches for active flow separation control using dielectric barrier discharge (DBD) plasma actuators are limited to relatively low-speed flows and atmospheric conditions. These limitations result in low feasibility of the DBDs for aerospace applications, such as active flow control at turbine blades, fixed wings, rotary wings, and hypersonic vehicles which require a satisfactory performance of the DBD plasma actuators at a wide range of conditions, including rarified flows and combustion mixtures. An optimization of the DBD plasma actuators should be achieved using an efficient, comprehensive, physically-based DBD simulation tool for different operation conditions. Tech-X Corporation proposes to develop a DBD plasma actuator simulation tool for a wide range of ambient gas pressures. The proposed tool will treat DBDs using either kinetic, fluid, or hybrid models, depending on the DBD operational condition. The proposed tool will be validated by comparison with the experimental and numerical data on the DBD investigations.

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Proposal # 09-2 A2.05-9058

OBJECTIVES

- ♦ Extend chemical and physical discharge model in VORPAL
- ♦ Extend hybrid capabilities of the proposed model
- ♦ Enhance computational speed of the proposed DBD Simulation Tool
- ♦ Demonstrate the DBD Simulation Tool through validation against experimental data at wide range of DBD operational conditions

Work Plan

- ♦ Extend air-chemistry and collision database for DBD plasma actuator modeling
- ♦ Implement photoionization model in VORPAL
- ♦ Enhance hybrid capabilities of the DBD Simulation Tool
- ♦ Integrate the multilevel mesh concept into the DBD Simulation Tool
- ♦ Develop the concept of adaptive time steps for multilevel meshes
- ♦ Implement the electric circuit model into VORPAL
- ♦ Perform an experimental study of the DBD plasma actuator at a wide range of ambient gas pressures

- ♦ Validate and verify the proposed DBD Simulation Tool

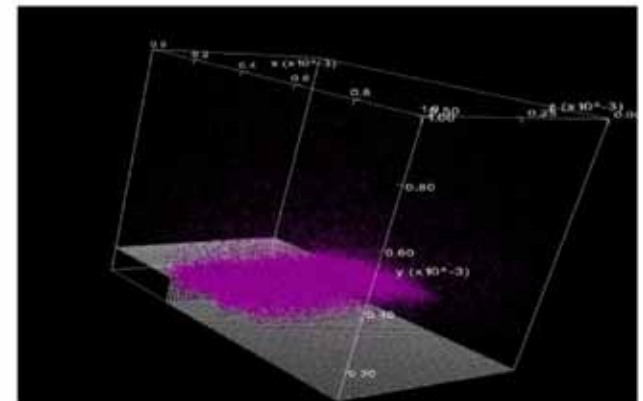
APPLICATIONS

NASA Applications

- ♦ Active flow separation control at turbine blade
- ♦ Active flow separation control at fixed and rotary wing aircrafts
- ♦ Active flow control at hypersonic vehicles

Non-NASA Applications

- ♦ Subsonic/hypersonic program of major aerospace companies
- ♦ Flow separation control at commercial airplanes and tilt rotor aircrafts
- ♦ Plasma aerodynamics
- ♦ Plasma medicine
- ♦ Plasma processing



3D simulation of the DBD plasma actuator

Uncertainty Quantification for Production Navier-Stokes Solvers

INNOVATION

The uncertainty quantification methods developed under this program are designed for use with current state-of-the-art flow solvers developed by and in use at NASA. The Phase 1 program demonstrated the CRISP CFD[®] error quantification and reduction code with simulations conducted using the NASA unstructured solvers FUN3D and USM3D. Phase 1 provided evidence supporting the suspected need for an error prediction code that matches the finite volume scheme of the Navier-Stokes solver itself. Phase 2 will continue this work by expanding Combustion Research's Error Transport Equation (ETE) solver to treat both classes of unstructured grid finite volume schemes.

Support for the CGNS standard will be implemented and will permit use of the Phase 2 product by a broader spectrum of potential users. Specific issues that affect numerical accuracy of the error predictions and how they propagate into integrated quantities such as lift and drag coefficients will be addressed. Reduction of error for large-scale meshes is a matter of equal importance, and improvements are planned that will provide for anisotropic grid refinement within the existing CRISP CFD mesh adaptation code. Finally, error quantification approaches for transient applications will be explored to expand these developments to problems that involve inherent unsteadiness and/or moving boundaries.

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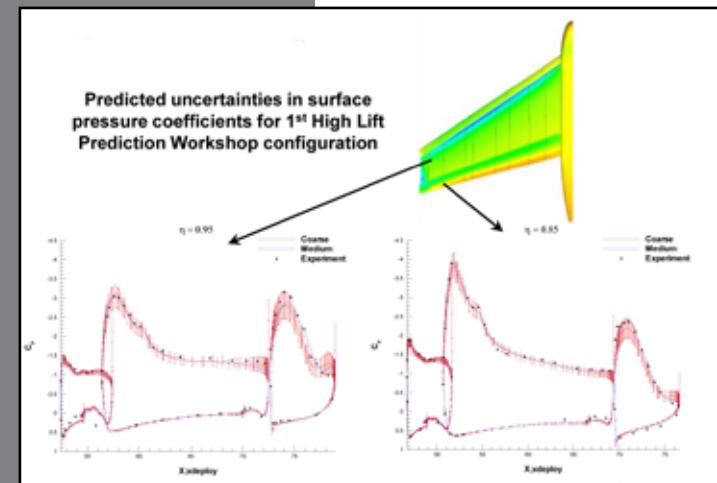
Proposal # 09-2 A2.05-9389

OBJECTIVES

- ♦ Extend and enhance current error prediction methods for use with various production Navier-Stokes solvers: node-centered and cell-centered; structured and unstructured
- ♦ Develop methods for determining whether a grid/solution sequence is in asymptotic range for valid error analysis
- ♦ Improve mesh adaptation/modification techniques for large-scale (100+ million cell) grids through anisotropic refinement
- ♦ Explore uncertainty quantification approaches for time-dependent applications, including moving boundary problems
- ♦ Validate error prediction and reduction methods on relevant aerodynamic problems of interest to NASA and industry

APPLICATIONS

- ♦ Supports NASA fundamental research programs in aeronautics
- ♦ Supports aerodynamic design in NASA programs for launch vehicles, space planes, and planetary entry vehicles
- ♦ Supports a broad spectrum of aerodynamic analyses conducted by major commercial aircraft manufacturers and Department of Defense contractors
- ♦ Applicable to variety of CFD applications beyond aerodynamics, including turbomachinery, combustors, and biomedical devices



Fiber-Coupled Spectrometer for TPS Materials

INNOVATION

EDA, Inc., in partnership with Pennsylvania State University, has shown previously that the concept of embedding fiber optics within ablative TPS material has merit and should yield a successful implementation of a spectrometer “window” during a Phase 2 development program.

Optical instrumentation, such as optical spectrometers, would provide benchmark data for fundamental flow, radiation, and materials modeling as well as provide operational correlations between vehicle reentry drag and radiation if implemented in a TPS flight test program. Without flight spectral data, and the appropriate modeling efforts, the power of prediction to assist in a new heat shield design does not exist for reentry into other planetary atmospheres. This is a severe limitation for future space exploration missions, which FiberPlug helps address.

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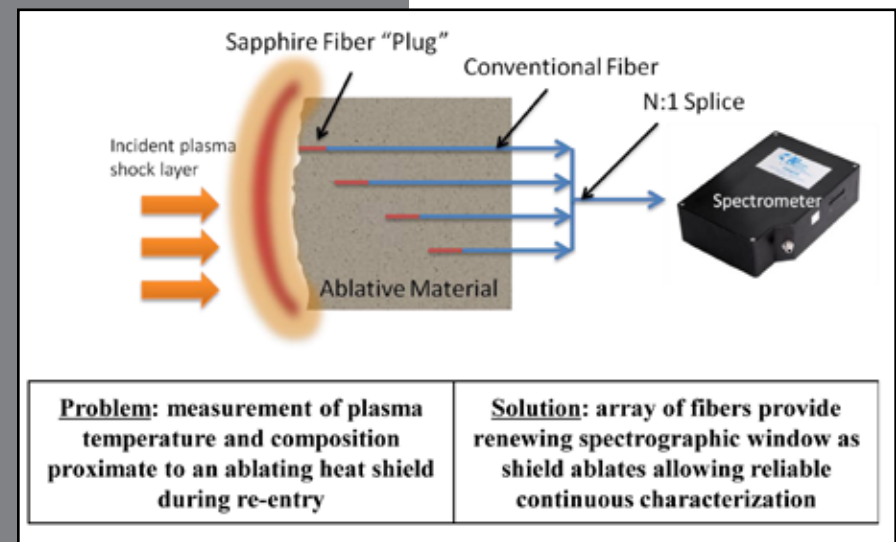
Proposal # 09-2 A2.06-8042

OBJECTIVES

- ♦ Simulate hypersonic flow environment using an arcjet plasma source
- ♦ Use a sapphire optical fiber to convey spectroscopic data about the plasma shock layer to the spectrometer
- ♦ Use spectroscopic data to improve and validate hypersonic radiation models
- ♦ Quantify performance in the VUV range (150 to 200 nm)
- ♦ Use optical plugs to determine heat shield ablation rates
- ♦ Develop a brassboard prototype of the spectrometer and integrated controller

APPLICATIONS

Hypersonic vehicles using TPS are of interest to NASA and Department of Defense. At the demonstration level, verification of TPS performance will be critical. For operational vehicles, the mission can be adapted in real time in response to performance data provided by FiberPlug. Improved characterization capabilities that can survive extreme environments will find a market in commercial applications as well.



Flight Dynamic Simulation With Nonlinear Aeroelastic Interaction Using the ROM–ROM Procedure

INNOVATION

ZONA Technology, Inc. proposes to develop an integrated flight dynamics simulation capability with nonlinear aeroelastic interactions by combining a flight dynamics model and an add-on nonlinear aeroelastic solver in a Simulink environment. This nonlinear aeroelastic solver is generated by interacting a nonlinear structural reduced order model (ROM) with a neural-network-based (NN-based) aerodynamic ROM and a gust ROM to provide the incremental aeroelastic forces and moments of a classical flight dynamics model. In this way, the flight dynamics model is limited to a minimum number of changes so that this integrated flight dynamics simulation remains in the framework of a 6-degrees-of-freedom simulation environment.

The nonlinear structural ROM employs an ELSTEP/FAT procedure that operates with commercial nonlinear finite element software to construct the nonlinear stiffness matrices. The NN-based and gust aerodynamic ROM is generated using a system identification technique operating on a CFD code to evaluate the weights and biases in a two-layer feed-forward NN system. The end product is called FuNL-DFS and can simulate the key aeroelastic coupling mechanism between nonlinear structural dynamics and nonlinear unsteady aerodynamics with classical rigid body dynamics. The FuNL-DFS system also can be used for control law development, maneuvering flight simulation, flight loads prediction, and handling quality assessment. The system will be validated with the flight test data of the Predator B Aircraft.

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Proposal # 09-2 A2.07-9816

OBJECTIVES

The overall objective of this Phase 2 effort is to develop the FuNL-DFS framework using a ROM–ROM procedure that includes the NN-based aerodynamic ROM, the ELSTEP/FAT nonlinear structural ROM, and an aerodynamic gust ROM in a Simulink environment. This FuNL-DFS framework will be validated with the flight test data of the General Atomics Aeronautical Systems' Predator B aircraft, which has a large wingspan and is an ideal testbed for the FuNL-DFS framework.

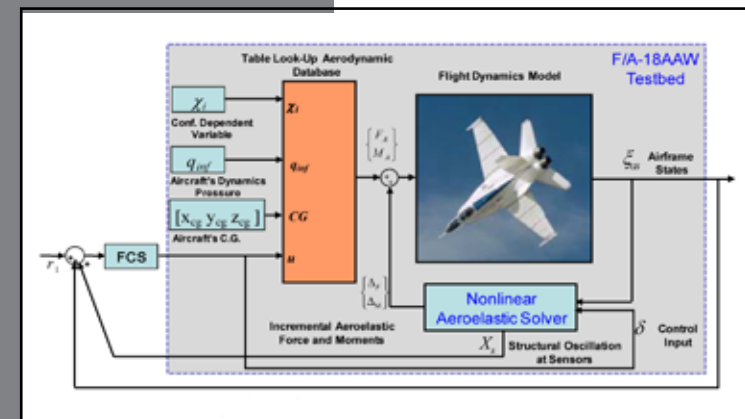
The ZONA team proposes a 2-year series of 10 tasks for the Phase 2 effort. The outcome of this 10-task effort will be a validated, production-ready FuNL-DFS System that is highly modularized so that any given flight dynamic model can be easily “plugged-and-played” into the commercialized FuNL-DFS System.

APPLICATIONS

FuNL-DFS will be marketed towards aerospace applications on a wide class of air vehicles such as:

- ♦ USAF's F-22 and F-35 aircrafts at Edwards AFB
- ♦ UASF's Hilda, sensorcraft as well as stealth and morphing UAV/UCAV
- ♦ DARPA's Morphing Aerostructure
- ♦ Boeing 787 and future executive jet designs such as those from Cessna and Raytheon

The proposed FuNL-DFS can also be applied to validate health management strategies specifically designed for aircraft designs with prominent aeroelastic characteristics.



Design Environment for Multi-Fidelity and Multi-Disciplinary Components

INNOVATION

Many of the most challenging categories of propulsion system development are related to the prediction of interacting effects between fluid loads, thermal loads, and the structural deflection. In practice, the interactions between technical disciplines are often not fully explored analytically, and the analysis in one discipline often uses a simplified representation of other disciplines as an input or boundary condition. For example, the fluid forces in an engine generate static and dynamic rotor deflection, but the forces themselves are dependent on the rotor position and its orbit. This practice ignores the interaction between the physical phenomena where the outcome of each analysis can be heavily dependent on the inputs (i.e., changes in flow due to deflection, changes in deflection due to fluid forces). Such a rigid design process also lacks the flexibility to employ multiple levels of fidelity in the analysis of each of the components.

The goals for this project are to develop and validate an innovative design environment that has the flexibility to simultaneously analyze multiple disciplines and multiple components with multiple levels of model fidelity. Development and demonstration of such a system will provide substantially superior capabilities to current design tools.

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Proposal # 09-2 A2.08-8224

OBJECTIVES

Successfully develop and validate the cycle-centric and CFD-centric fluid structure interaction architectures.

Work Plan

- ◆ Develop FSI capability in NASA CFD solver and commercially available solver
- ◆ Implement cycle-centric FSI software tool
- ◆ Implement CFD-centric FSI software tool
- ◆ Verify and validate the functions for numeric zoom, fluid structure interaction, multi-discipline, and multi-fidelity analysis
- ◆ Deliver the system to NASA and train engineers in its use

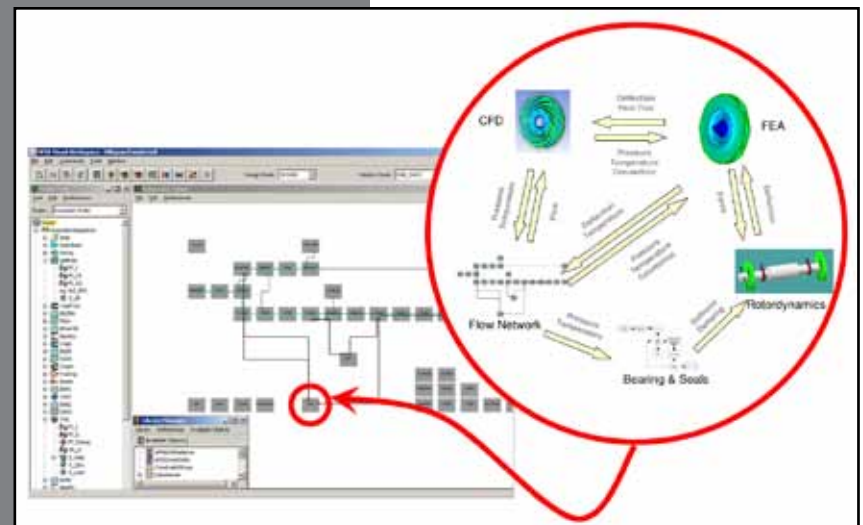
APPLICATIONS

NASA Applications

- ◆ Development of propulsion systems
- ◆ Multi-physics analysis
- ◆ Design cycle for turbomachinery systems

Non-NASA Applications

- ◆ Directly applicable to design and development of a wide range of turbomachinery systems



Discrete Geometry Toolkit for Shape Optimization

INNOVATION

Simulation-based design optimization has been steadily maturing over the past two decades, but not without its own unique and persistent challenges. The proposed project will develop a novel solution to one of the long-standing bottlenecks in simulation-based design optimization. Optimal, LLC will develop a flexible geometry toolkit for shape parameterization and modification to be used for design optimization. With the discrete geometry toolkit, shape modifications will be achieved via an elegant and intuitive “plug-and-play” approach, providing engineers with a wide variety of options for shape parameterization, shape deformation, and geometric constraint imposition. The geometry toolkit will be composed of independent modules and will be easily integrated into existing or future analysis and design environments. Optimal’s approach will offer a modular and intuitive means to interactively synthesize appropriate modifications to discrete geometry shapes in a design optimization setting, including the specification of geometric constraints and interdisciplinary data transfer.

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Proposal # 09-2 A2.08-8824

OBJECTIVES

- ♦ Continue componentizing a variety of digital geometry data objects and geometric algorithms (Months 1-9)
- ♦ Develop a unified approach to component-based geometry suitable for both Cartesian and finite-volume CFD solvers (Months 7-15)
- ♦ Refine the discrete toolkit for multiple modes of operation including C++, C, F90, Python, Ruby, C#, .NET, and a cross-platform GUI (Months 13-21)
- ♦ Perform challenging aerospace and biomedical demonstration cases with a particular focus on NASA needs (Months 22-24)

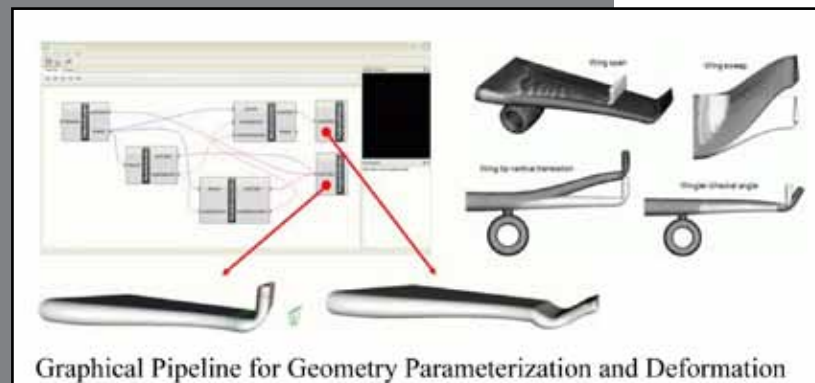
- ♦ NPSS (NASA Glenn)
- ♦ CART3D adjoint-based design (NASA Ames)
- ♦ SSME component design (NASA Marshall)
- ♦ Hypersonic vehicle design (NASA Dryden)
- ♦ AVEC design environment (Air Force Research Lab)
- ♦ Rotary blood pump design (Thoratec, CardiacAssist, JarvikHeart)
- ♦ Plug-in for Phoenix Integration ModelCenter & CFDRC MDICE
- ♦ Commercially-viable CFD-based designs

All Phase 1 tasks were performed on schedule and to completion.

APPLICATIONS

The toolkit can immediately benefit the following design efforts:

- ♦ ModelCenter-based design environments (NASA Langley)



Flight Adaptive Blade for Optimum Rotor Response (FABFORR)

INNOVATION

While past research has demonstrated the utility and benefits to be gained from the application of advanced rotor system control concepts, none have been implemented to date on a production military or commercial rotorcraft. A key contributor to this fact is the inherent cost associated with installation and maintenance of these control systems, since many system designs require the replacement of a helicopter's rotor blades, rotor hub components, or both. The proposed work addresses this deficiency through the development of an on-blade, full-span camber control system that reaps many of the known benefits of advanced rotor control. The system employs a retrofit design approach that has the potential to achieve production status due to its lower risks and costs compared to previous system concepts. The design leverages past work in the use of smart-material actuated bi-stable tabs for rotor blade tracking, with a newer integral actuation concept that will lead toward a more robust and flight-worthy design.

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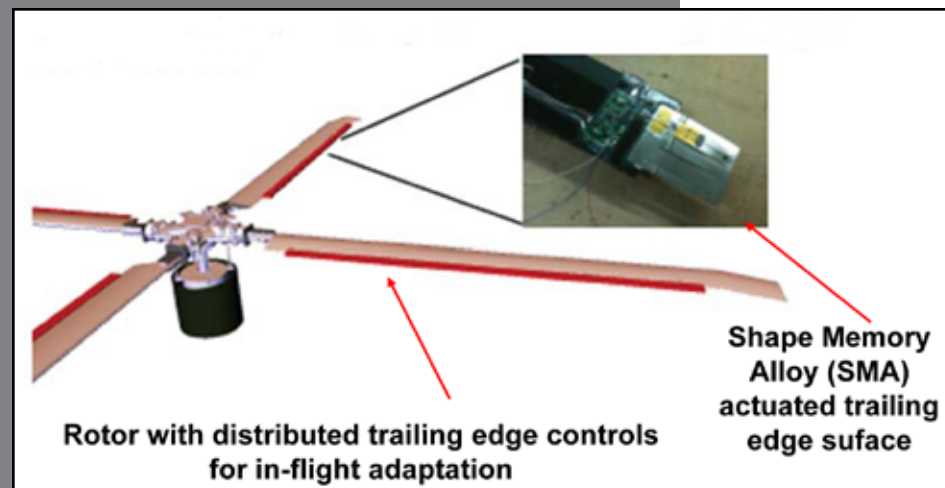
OBJECTIVES

- ◆ Build on enhanced shape memory alloy-based, bi-stable rotor blade trailing edge tab design from Phase I to provide multiple-element discrete control of entire trailing edge deflection.
- ◆ Perform analysis, benchtop, wind tunnel, and whirl stand testing of actuation concepts for quantifying actuation power requirements, weight, and performance improvements.

- ◆ In-flight adjustment of blade properties enhances rotorcraft performance and utility across the flight envelope.
- ◆ Low power requirements, small size, and minimal weight permit retrofit installation onto existing rotor blades.

APPLICATIONS

This system provides an important advance over current rotorcraft flight control actuation technologies and directly supports NASA's strategic objective of demonstrating enhanced vehicle capability in the flight test environment.



Embedded Data Acquisition Tools for Rotorcraft Diagnostic Sensors

INNOVATION

Ridgetop's innovation addresses the need for improved capabilities for detecting wear in the drive gears inside helicopter gearboxes. Rotorcraft drive trains must withstand enormous pressure while operating continuously in extreme temperature and vibration environments. Captive components, such as planetary and spiral bevel gears, see enormous strain but are not accessible to fixed instrumentation such as a piezoelectric transducer. Thus, it is difficult to directly monitor components that are most susceptible to damage.

Ridgetop has developed an embedded data acquisition module that overcomes these limitations. This innovation is a self-contained data processing unit within a specialized fixture that installs directly inside the hubs of rotating gear parts. From this location, it detects and transmits high-fidelity prognostic data to a fixed transceiver. The sensor is based on MEMS technology and uses innovative circuit designs to capture high bandwidth data and transmit it wirelessly from inside an operational helicopter transmission.

In Phase 2, Ridgetop will build the module and acquisition system, and demonstrate it at the NASA Glenn rotorcraft transmission testbed. Ridgetop will provide evidence that the innovation gives superior fidelity by making side-by-side comparisons with the current fixed-sensor setup. Ridgetop will tie in data collection with prognostics and advanced diagnostic approaches, make enhancements, and show an improvement in failure detection horizon times. The company also will develop a data interface between the wireless sensor port and a standard HUMS communication bus. Finally, Ridgetop will develop a commercialization path by demonstrating the technology to airframe manufacturers.

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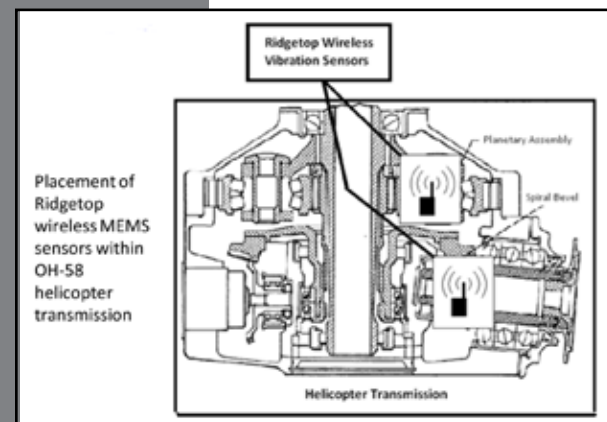
Proposal # 09-2 A2.09-9940

OBJECTIVES

- ♦ Build module and acquisition system and demonstrate at NASA Glenn rotorcraft transmission testbed
- ♦ Provide evidence that the innovation gives superior fidelity by making side-by-side comparisons with current fixed sensor setup
- ♦ Tie in data collection with prognostics and advanced diagnostic approaches, make enhancements, and show an improvement in failure detection horizon times
- ♦ Develop a data interface between the wireless sensor port and a standard HUMS communication bus
- ♦ Develop a commercialization path, by demonstrating the technology with airframe manufacturers

APPLICATIONS

- ♦ The technology developed in this program can be used to measure accumulated stress and aging in electromechanical components. Accordingly, it is applicable to asset-sustainment programs for new and legacy aircraft.
- ♦ Sikorsky has expressed interest in this technology as a potential upgrade to its test beds.
- ♦ Goodrich is interested in interfacing the sensor to its HUMS network.
- ♦ Boeing is interested in using the outcomes of the research to help develop improved gear sets.



Design Concepts for Cooled Ceramic Matrix Composite Turbine Vanes

INNOVATION

The work proposed herein is to demonstrate that the higher temperature capabilities of Ceramic Matrix Composites (CMCs) can be fully utilized to reduce emissions and improve fuel consumption in gas turbine engines. The work involves closely coupling aerothermal and structural analyses for the first stage vane of a high-pressure turbine (HPT). These vanes are actively cooled, typically using film cooling. Ceramic materials have different structural and thermal properties than conventional metals used for the first stage HPT vane. Vane configurations that satisfy CMC structural strength and life constraints, while maintaining vane aerodynamic efficiency and increasing mainstream gas temperature for improved engine performance, will be identified. The proposed work will examine modifications to vane internal and external configurations to achieve the desired objectives. Thermal and pressure stresses are equally important, and both will be analyzed. Three-dimensional fluid and heat transfer analyses will be used to determine vane aerodynamic performance and heat load distributions.

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Proposal # 09-2 A2.10-9062

OBJECTIVES

Demonstrate that an EBC-coated CMC vane can be used in existing and future engines.

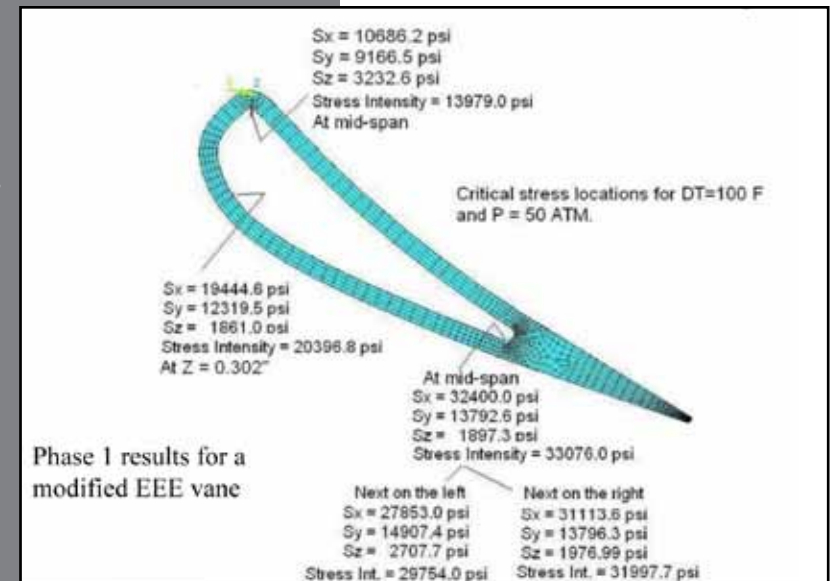
Work Plan

1. Perform thermal analysis for EBC vane heat load distributions
2. Evaluate stress distributions for EBC vane
3. Evaluate internal vane modifications to reduce stresses
4. Evaluate increased stress due to film cooling holes
5. Evaluate effects of a very low aspect ratio vane
6. Evaluate test article vane
7. Evaluate external vane shape modifications
8. Generate input for cycle analysis
9. Perform probabilistic analysis
10. Perform high-temperature creep analysis
11. Design and fabricate the CMC test article

APPLICATIONS

This analysis is beneficial for a wide range of gas turbine engine applications:

- ♦ Small gas turbines (rotary wing application)
- ♦ Commercial transport aircraft
- ♦ Supersonic aircraft
- ♦ Current combined cycle gas turbines
- ♦ Future clean coal cycles
- ♦ Recuperated turbines





AIRSPACE SYSTEMS PROGRAM

Goals of the Airspace Systems Program are to develop and demonstrate concepts, capabilities, and technologies that will enable major increases in air traffic management effectiveness, flexibility, and efficiency. A major objective of Airspace Systems Program is to meet capacity and mobility requirements of the Next Generation Air Transportation System, as set out by the multi-agency Joint Planning and Development Office. Accordingly, program goals are to:

- Improve mobility, capacity, efficiency, and access of the airspace system
- Improve collaboration, predictability, and flexibility for airspace users
- Enable accurate modeling and simulation of air transportation systems
- Accommodate operations of all classes of aircraft
- Maintain system safety and environmental protection



Statistical Decision Support Tools for System-Oriented Runway Management

INNOVATION

The feasibility of developing a statistical decision support system to manage traffic flow in airport terminals and balance runway loads was demonstrated in the Phase 1 research. The methodology employed an advanced estimation algorithm based on a queuing network model of the runway and the terminal areas and statistical decision theory to formulate traffic flow decisions. Radar data from the San Francisco terminal was used in the feasibility demonstration. Component technologies developed in Phase 1 work can be used for synthesizing real-time statistical decision support tools for runway configuration management and arrival/departure scheduling.

Phase 2 work will use the Phase 1 algorithms for developing decision support tools for NASA's System-Oriented Runway Management (SORM) Program. Queuing networks of runways, taxiways, gates, and terminal airspace will form the foundation of the decision support tool. Predicted demand, historic traffic data, and real-time measurements will be combined in an estimator to generate the statistical distributions of the queuing network parameters. These distributions will then be used in conjunction with methods from statistical decision theory to generate actionable decisions. Phase 2 research will produce a software package implementing these algorithms, which can be evaluated in human-in-the-loop and operational settings during Phase 3.

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Proposal # 09-2 A3.01-8137

OBJECTIVES

- ♦ Formulate queuing network models for KSFO and KDFW airports and terminal airspace
- ♦ Develop a particle filter-based estimator for queuing network parameters that uses historic traffic data, predicted traffic demand and weather, and actual operations data
- ♦ Formulate statistical decision theory based algorithms for Runway Configuration Management (RCM) Combined Arrival/Departure Scheduling (CADRS)
- ♦ Develop a software package implementing the RCM CADRS algorithms to create SORM decision-support tools
- ♦ Evaluate SORM decision tools using traffic data from KSFO and KDFW

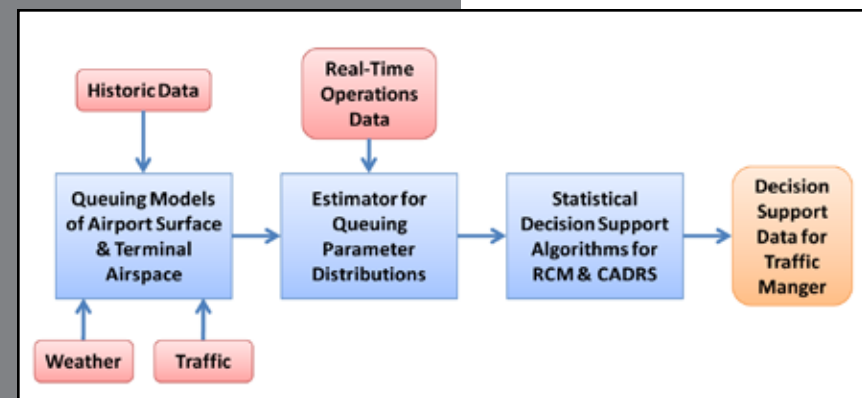
APPLICATIONS

NASA Applications

Algorithms and tools developed under Phase 2 are directly applicable in the SORM program.

Non-NASA Applications

Queuing networks estimation algorithm and statistical decision support methods are applicable to a wide variety of transportation and logistics problems.



Estimation and Prediction of Unmanned Aerial Vehicle Trajectories

INNOVATION

There is serious concern about the introduction of Unmanned Aerial Vehicles (UAVs) in the National Airspace (NAS) because of their potential to increase the risk of collision between aircraft. At present, many UAV platforms lack a sense and avoid (SAA) capability to mitigate collision risk, and this has prevented both government and private contractors from using these platforms in critically needed reconnaissance, surveillance, and security enforcement missions. To demonstrate an SAA capability that is applicable to a wide range of UAV platforms, advanced trajectory estimation and prediction algorithms are developed and used to exploit small collision avoidance radar currently under development for UAV operation. Collision prediction algorithms assess potential risk in probabilistic terms using adaptive techniques that permit accurate predictions across long time horizons. Techniques to ensure these predictions are accurate increase the utility of the developed SAA capability for realistic scenarios.

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Proposal # 09-2 A3.01-8419

OBJECTIVES

- ♦ Extend to multi-intruder scenario
- ♦ Understand hardware specific issues
- ♦ Produce reliable, high utility collision prediction algorithms
- ♦ Implement a software prototype
- ♦ Demonstrate the benefit of SAA in reducing collision risk

Work Plan:

- ♦ Implement a radar model
- ♦ Mature the algorithms
- ♦ Implement software prototype
- ♦ Integrate with tracking system
- ♦ Demonstrate SAA capability
- ♦ Conduct USTAR transition study

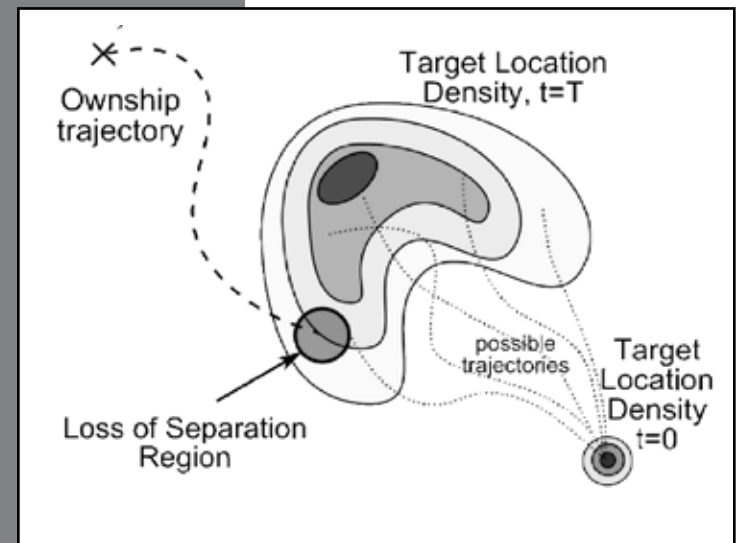
APPLICATIONS

NASA Applications

- ♦ Prototype for UAV integration into NAS as part of NextGen Airspace
- ♦ Plug-in for future ATM concept evaluation

Non-NASA Applications

- ♦ Exploit Colorado Engineering Inc. USTAR radar
- ♦ Plug-in for Ultra's AFTS product
- ♦ Deploy to Navy or other military UAV platforms



Stochastic Queuing Model Analysis to Support Airspace Super Density Operations (ASDO)

INNOVATION

NASA has been involved in extensive research efforts to develop advanced concepts and technologies for the Next Generation Air Transportation System (NextGen) under different Research Focus Areas (RFAs). The Airspace Super Density Operations (ASDO) RFA seeks to develop efficient terminal area operations. It is expected that multiple ASDO concepts will be interacting with one another in a complex non-deterministic manner. Therefore, the overall terminal system performance may not be a straightforward combination of individual performance indices. It is also crucial that the overall system performance be robust to wind and operational uncertainties. The proposed research effort seeks to develop a fast-time stochastic analysis tool based on queuing theory that can be used to evaluate the interaction and combined performance of multiple ASDO concepts. The utility of the approach was demonstrated under Phase 1 research.

Phase 2 research seeks to achieve the enhancements and developments outlined below.

OBJECTIVES

1. Enhance the queuing model and discrete event simulation
 - a. Develop NorCal metroplex model
 - b. Enhance the wind uncertainty model
2. Accelerate the execution of the stochastic queuing simulation
 - a. Implement optimized C code
 - b. Use a fast Monte Carlo simulation through GPU computing
3. Develop software to assist NASA research in the airport terminal area
 - a. Automate assembly of queuing models
 - b. Develop plugin/toolbox for STASS
4. Demonstrate utility through terminal area studies
 - a. Perform benefit analysis of NextGen ASDO concepts
 - b. Perform a stochastic evaluation of the traffic flow efficiency for terminal area routes
 - c. Reconfigure the terminal area/metroplex runway
 - d. Provide tuning parameters feedback for various ASDO algorithms
5. Explore the utility of the developed queuing model framework as a planning/decision support tool

6. Develop a queuing model based on sequencing, scheduling, and merging and spacing algorithms for terminal area operations

APPLICATIONS

Primary NASA Application

Stochastic analysis tool to evaluate proposed NextGen concepts in the terminal area

Non-NASA Applications

1. As a planning tool by the FAA to forecast future state of the terminal area for TFM decision-making algorithms
2. By airline operations centers to make canceling and rescheduling decisions in response to off-nominal events, such as adverse weather
3. In rapid prototyping tools that design terminal area routes and procedures to evaluate the efficiency of designed routes

CONTACT INFORMATION

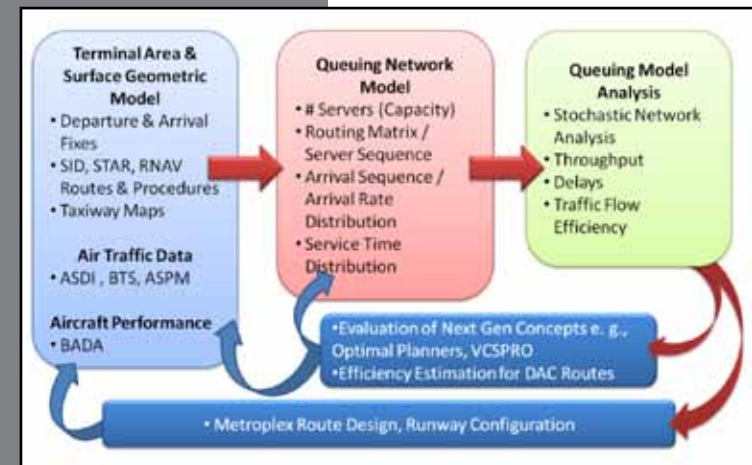
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COTR

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Proposal # 09-2 A3.01-8549



Market Mechanisms for Airspace Flow Program Slots

INNOVATION

Metron Aviation, Inc. proposes to design a system to support a marketplace in which flight operators can exchange arrival slots in traffic flow management (TFM) initiatives such as airspace flow programs (AFPs) and ground delay programs (GDPs) while requiring no changes in FAA automation or procedures. The advent of AFPs in 2006 generated many potentially exchangeable resources that owners might want to trade. Metron believes that NAS users and the FAA would embrace a marketplace that would enable users to collectively reduce their operating costs resulting from NAS congestion.

Both FAA and NASA research have highlighted the need for efficient and equitable allocation of NAS resources and increased operational flexibility. Market-based mechanisms have been suggested for transferring system-imposed delays from more critical to less critical flights. No such capability is available to NAS users today. Metron plans to show how the advent of AFPs changes the forces at work in a slot-trading marketplace, making those functions much more valuable to flight operators.

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Proposal # 09-2 A3.01-8820

OBJECTIVES

- ◆ Prepare demo and presentation to airline customers
- ◆ Run HITLs using historical and live data; evaluate benefits
- ◆ Determine Metron's business model when acting as a transaction clearinghouse
- ◆ Define infrastructure requirements
- ◆ Write client and server software
- ◆ Develop methods to incorporate operator-provided flight information
- ◆ Validate cost and utility functions
- ◆ Evaluate potential for deploying other market-based approaches within the same architecture
- ◆ Evaluate implications of best-equipped/best-served policy
- ◆ Develop a business plan for international deployment

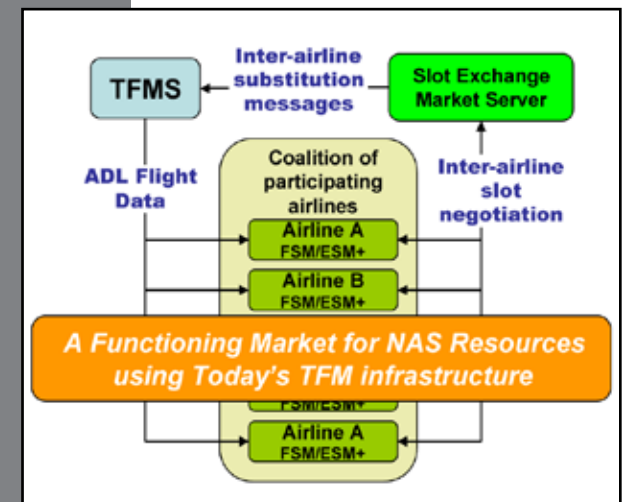
APPLICATIONS

NASA Applications

- ◆ Further NextGen Air Traffic Management Airspace Project by progressing toward a safe, efficient, and high-capacity airspace system using a market-based resource allocation mechanism
- ◆ Provide an operational platform for the evaluation and accelerated deployment of other NASA market-based approaches to ATM

Non-NASA Applications

- ◆ Flight operators (airlines, cargo carriers, general aviation)
- ◆ Flight research organizations
- ◆ Global ATM systems



Unmanned Aerial Vehicle Integration into the NAS

INNOVATION

Technological innovations have enabled a wide range of aerial vehicles that can be remotely operated. Viable applications include military missions, law enforcement, border patrol, weather data collection, telecommunications, land use imaging, and cargo transport. NASA and other organizations have invested heavily in this unmanned aerial vehicle (UAV) research. UAVs can be flown in the National Airspace System (NAS) today, but only with special permission from the FAA—a process that often takes 60 to 90 days. Moreover, permission is often contingent on heavy restrictions, such as accompanying the UAV with a manned chase plane, thereby nullifying the cost savings of a UAV. Full fruition of UAV technology will require incorporation of UAVs into mainstream air traffic management (ATM) practices, including traffic flow management flow control programs and possible creation of special use airspace (SUA). In this SBIR, Metron Aviation, Inc. proposes a UAV-to-traffic flow management interface, the Awareness, Integration, and Management of Unmanned Aircraft Systems (AIM–UAS). This will allow traffic managers to anticipate and track UAVs. In turn, this will also allow UAV operators to understand their impact on commercial air traffic and coordinate their involvement in traffic management activities.

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Proposal # 09-2 A3.01-8821

OBJECTIVES

- ♦ Build a prototype Web-based interface of the AIM–UAV tool. Users will be ATM, visual flight rules (VFR) flight operators, and operators of missions such as earth science, aerial photography, border patrol, and law enforcement.
- ♦ Identify current and future impediments to smooth operation of UAVs in the NAS.
- ♦ Further investigate and refine UAV mission and flight planning needs.
- ♦ Develop a cadre of UAV operational scenarios to capture the full spectrum of future UAV missions.
- ♦ Identify other (non-ATM) consumers of UAV operational information.

- ♦ Studying new TFM procedures that exploit 4DT management, TBO, CD&R between commercial aircraft and UAVs, DAC management of SUA for UAVs, and PBS
- ♦ Investigating benefits of UAV control strategies
- ♦ Studying how UAV operators interact with TFM optimization
- ♦ Investigating human factors to evaluate benefits and tradeoffs of the collaboration of UAV users with commercial airlines

Non-NASA Applications

- ♦ Operators of cargo flights, crop dusters, and surveyors
- ♦ Agencies conducting flights in dangerous situations (Departments of Defense and Homeland Security)

APPLICATIONS

NASA Applications

- ♦ NASA UAV mission and flight and planning
- ♦ Identifying current and future impediments to NAS integration of UAVs



Integrated Testbed for Environmental Analysis of NextGen Concepts using ACES

INNOVATION

The key innovation in this effort is the development of an industrial-grade analysis testbed to integrate simulation tools, such as Advanced Concepts Evaluation System (ACES), with aviation environmental effects models, such as the Aviation Environmental Design Toolkit (AEDT), to provide a “360-degree” evaluation of new operational concepts. The testbed will be demonstrated by producing a 360-degree evaluation of advanced Next Generation Air Transportation System concepts such as time-based merging and spacing at ATL airport, high-density metroplex concepts, and the efficiency of new route structures with environmentally responsible aircraft using RNAV routing. The industrial-grade software will be implemented in Java and can potentially reduce the analysis time for combined performance/environmental analyses by several months over the current state of the art.

OBJECTIVES

Objective 1: Implement a commercial-grade integrator designed to seamlessly connect the ACES performance model with the AEDT environmental model. The proof-of-concept integrator from Phase 1, which was prototyped in MATLAB, will be ported to Java and all remaining issues with the integration will be resolved.

Objective 2: Demonstrate the utility of the integrator with three different NextGen-oriented analyses, showing the value of the 360-degree analysis approach.

Objective 3: Validate the resulting system through comparison with standard models as well as comparison with actual field data, such as radar or other data, to provide confidence in the resulting system.

APPLICATIONS

Potential applications include NASA, the FAA, and industrial companies whose business it is to do either environmental assessment or performance analysis. Capability would be used to develop an integrated picture of the performance and environmental assessment of future proposed projects. Airports with planned improvements, large metroplexes (approximately 14) with planned system upgrades, and air traffic control centers are potential customers.

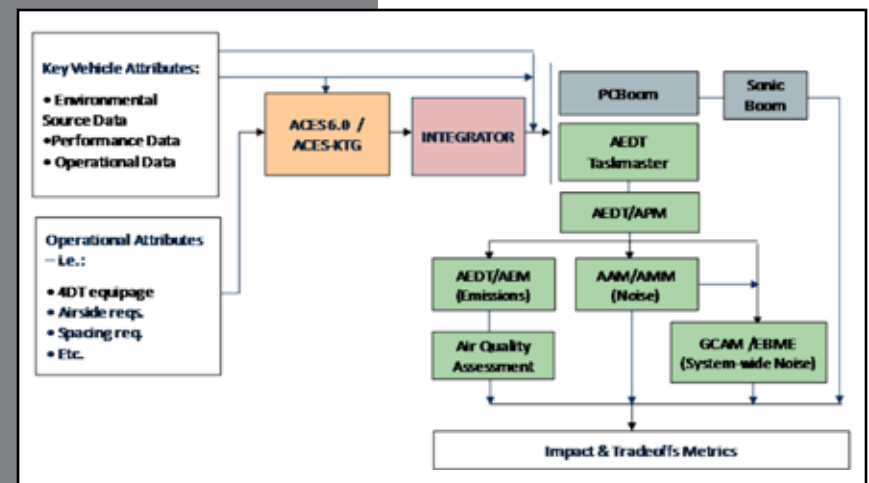
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Proposal # 09-2 A3.02-8211



Lidar Wind Profiler for the NextGen Airportal

INNOVATION

The development of a standoff sensor that can measure 3D components of wind velocity in the vicinity of an airport has the potential to improve airport throughput, safety, and efficiency. The goal of this research is to develop a Lidar Wind Profiler (LWP) that uses multiple near-parallel lidar beams to track the motion of atmospheric aerosol structures and extract multi-component wind data. In Phase 1, the measurement requirements were analyzed and used to develop a numerical performance model of the prototype system. In addition, an eye safety analysis was conducted and a conceptual design of the LWP prototype was developed. Studies were conducted with a breadboard in order to demonstrate improvements in spatial and temporal resolution of the system and to obtain more data to further refine the system requirement and algorithm.

In Phase 2, the LWP design will be finalized and a high power laser design will be combined with narrow pulse-width generation technology as well as an optical parametric oscillator in order to generate a wavelength of 1,550 nm. The algorithm will be optimized and extended to measurements in all three dimensions using a multi-beam lidar system. Techniques to extract atmospheric turbulence and detect aircraft wake vortices will be developed. A software package will be developed that will include the following: a front-end graphical user interface (GUI) for displaying the data and for interfacing with the operator; a real-time data-processing module; a data acquisition module; and a data storage and retrieval module. At the end of Phase 2, the LWP prototype will be field tested and evaluated using validation data from ultrasonic anemometers.

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Proposal # 09-2 A3.02-8812

OBJECTIVES

- ◆ Demonstrate three-component velocity measurements using an aerosol lidar (range resolution: 10 m, time resolution of ≤ 10 sec, real-time [data latency ≤ 10 sec])
- ◆ Detect atmospheric turbulence
- ◆ Detect aircraft wake vortices

Work Plan

- ◆ Finalize prototype design (preliminary and critical design review)
- ◆ Develop the laser (high average power, narrow pulse [≤ 5 ns], 1,550 nm wavelength)
- ◆ Develop the software (wind retrieval, turbulence, wake vortices)
- ◆ Integrate, test, and validate the prototype

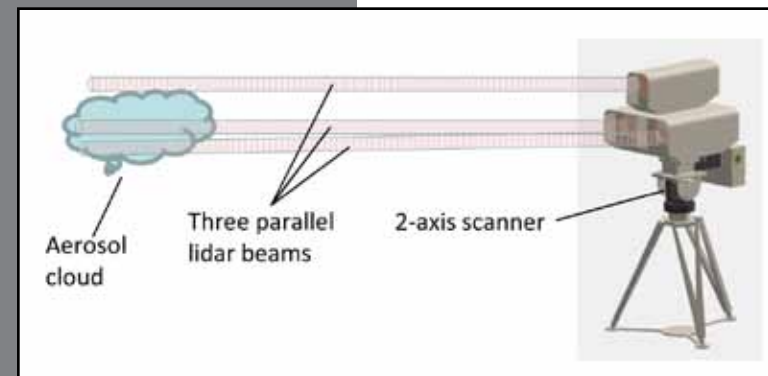
APPLICATIONS

NASA Applications

- ◆ Airport Wind Sensing
- ◆ Aircraft Wake Vortex Detection
- ◆ Weather Monitoring
- ◆ Test Facility Instrumentation
- ◆ Launch Vehicle Ballistic Corrections

Non-NASA Applications

- ◆ Sniper/artillery/missile
- ◆ Ballistic corrections
- ◆ Building aerodynamics RDT&E for aerospace/automotive
- ◆ Wind turbines



ATC Operations Analysis via Automatic Recognition of Clearances

INNOVATION

Recent advances in airport surface surveillance have motivated the creation of new tools for analysis of Air Traffic Control (ATC) operations, such as the Surface Operations Data Analysis and Adaptation (SODAA) tool, which is being used by NASA to conduct airport ATC operations analysis. What is missing from ATC operations analysis, however, is accessible and reliable data regarding the clearances issued by the controller and other communication conducted with the pilot that influences the behavior seen in the surveillance data. The reliance on voice communication in ATC operations presents challenges to the researcher who is trying to obtain data and conduct detailed analyses of ATC operations. During the Phase 1 effort, Mosaic ATM, Inc. designed and developed a prototype system to perform automatic speech recognition (ASR) of ATC clearances. The firm demonstrated the feasibility of recognizing ATC clearances from speech audio data and associating the clearance data with the flight that is the subject of the clearance.

In the Phase 2 effort, Mosaic will create a complete prototype of the ATC speech recognition, processing, and analysis capabilities in SODAA. In addition, the company will integrate ATC speech recognition capabilities into a real-time application in the Surface Management System (SMS).

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Proposal # 09-2 A3.02-9691

OBJECTIVES

Technical Objectives

- ♦ Achievement of sufficient accuracy of ASR for ATC
- ♦ Prototype of Clearance Data Collection Architecture
- ♦ Real-Time ASR Data Acquisition in SMS

Work Plan

- ♦ Develop Automatic ATC Speech Recognition Algorithm Enhancement
- ♦ Enhance SODAA data elements and query features
- ♦ Implement data collection architecture
- ♦ Integrate real-time speech data acquisition into SMS

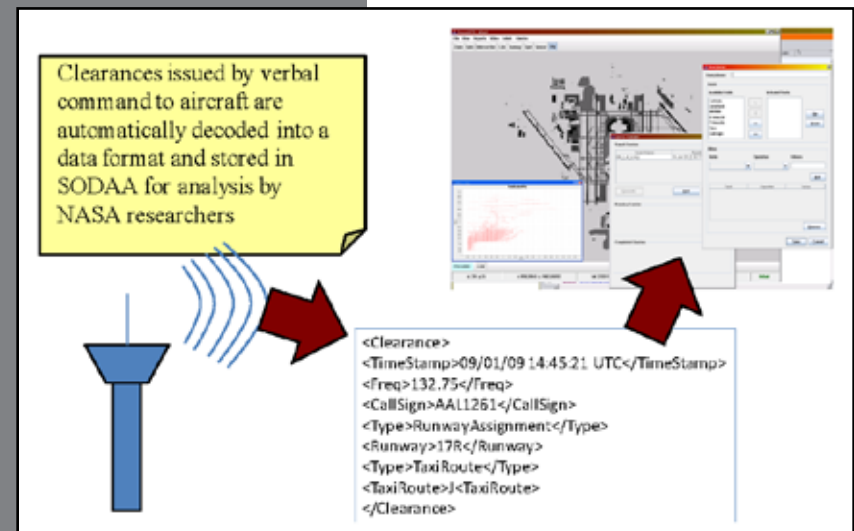
APPLICATIONS

NASA Applications

- ♦ Powerful infrastructure and capabilities to enable new research capabilities for NASA
- ♦ Increased visibility into ATC operations

Non-NASA Applications

- ♦ Integration of ASR into SMS/SDSS to improve prediction performance and to support passive taxi conformance monitoring
- ♦ Integration into airline surface applications to improve situational awareness

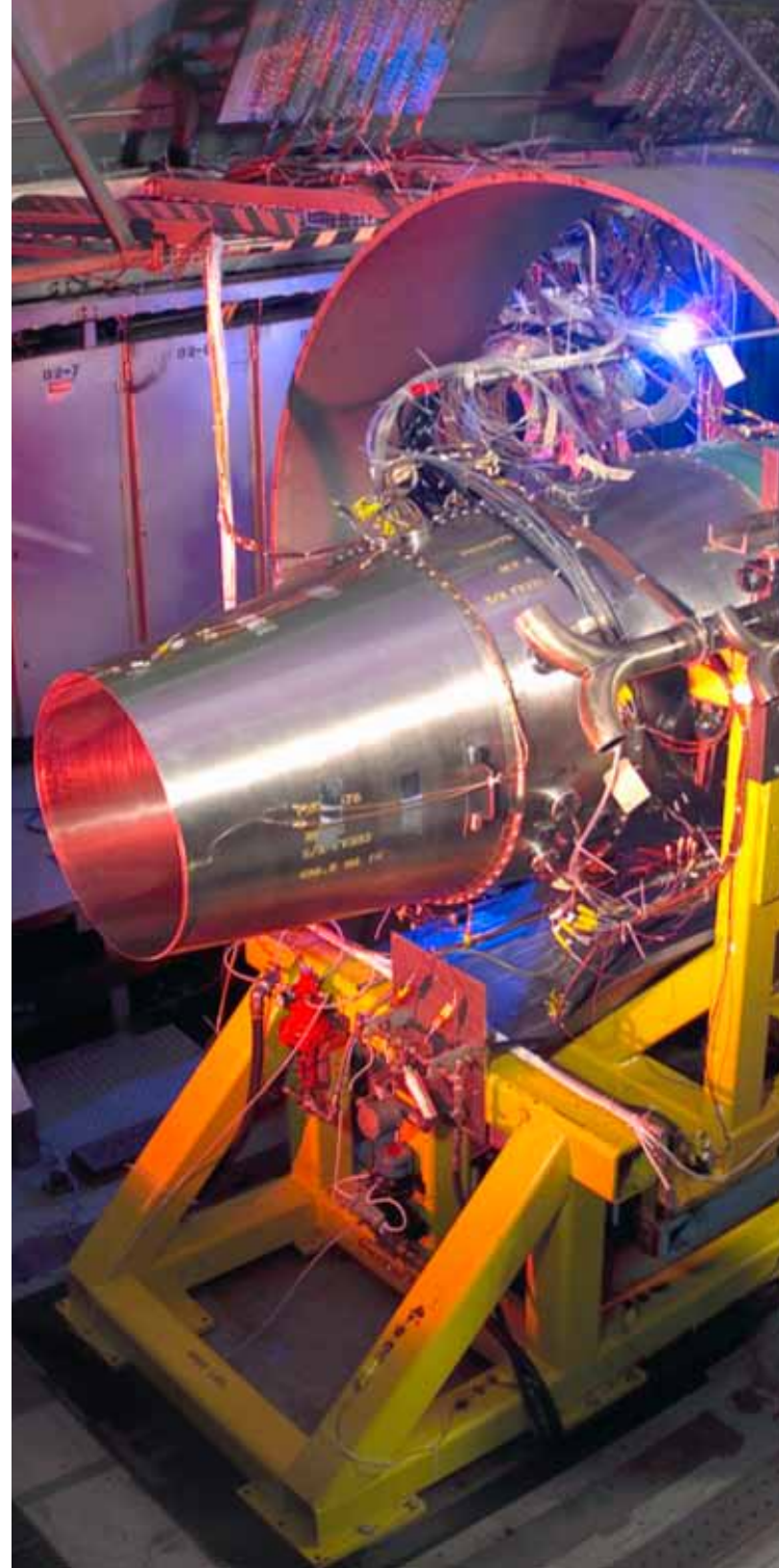




AERONAUTICS TEST PROGRAM

The mandate of ARMD's Aeronautics Test Program (ATP) is to ensure that NASA, other government agencies, and commercial customers have access to the flight test capabilities when they need them and at reasonable costs. Four NASA centers—Ames Research Center, Dryden Flight Research Center, Glenn Research Center, and Langley Research Center—operate ATP facilities and provide an extensive array of services in their respective areas of expertise. These include major ground test systems, such as wind tunnels and propulsion test facilities, as well as flight test capabilities including flight vehicles and supporting infrastructure. The program:

- Manages NASA's ground and flight test capabilities at a strategic level, applying centralized policies and procedures across NASA centers
- Ensures that these assets operate efficiently and cost effectively
- Determines, maintains, and improves the minimum set of core testing capabilities
- Works with other government agencies to optimize U.S. capabilities



Blade Vibration Measurement System for Unducted Fans

INNOVATION

With propulsion research programs focused on new levels of efficiency and noise, there are two emerging avenues for advanced gas turbine technology: the geared turbofan engine and the ultra-high bypass ratio fan engine. Both of these candidates are being pursued as collaborative research projects between NASA and engine original equipment manufacturers (OEMs). The high bypass concept from GE Aviation is an unducted fan which features a bypass ratio of over 30, along with the accompanying benefits in fuel efficiency.

The innovation being developed for this project is an improvement in the test and measurement capabilities of the unducted fan blade dynamic response. In the course of this project, Mechanical Solutions, Inc. (MSI) will work with GE Aviation to define the requirements for fan blade measurements, to leverage MSI's radar-based system for compressor and turbine blade monitoring, and to develop, validate, and deliver a non-contacting blade vibration measurement system for unducted fans.

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Proposal # 09-2 A4.01-8214

OBJECTIVES

- ◆ Develop and validate the non-contacting measurement system for unducted fans
- ◆ Integrate the measurement system with existing technology at GE Aviation
- ◆ Deliver a working system to NASA

Work Plan

- ◆ Complete design, analysis, and manufacture of antenna, waveguide, and radar subsystem
- ◆ Work with GE to verify operation via spin pit testing using composite rotor
- ◆ Work with GE to install in the NASA Glenn wind tunnel for planned UDF tests

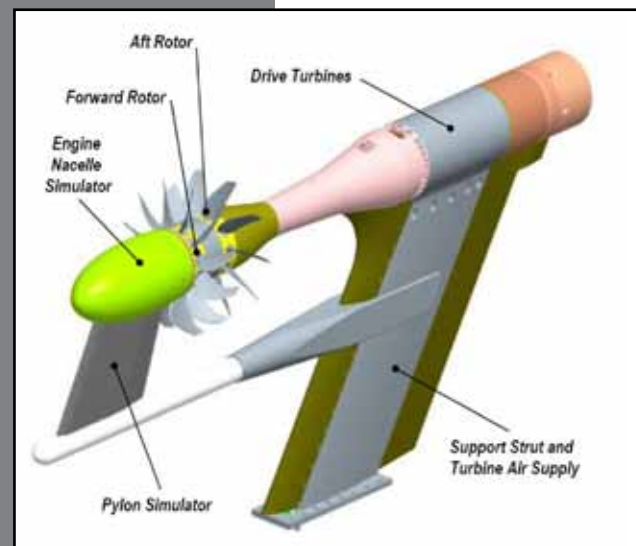
APPLICATIONS

NASA Applications

- ◆ Improves measurement capability of wind tunnel facility
- ◆ Provides important data for development of robust unducted fan
- ◆ Applies to other fan and propeller test facilities

Non-NASA Applications

- ◆ Fan, propeller, and wind turbine blade development testing



Piezoelectric MEMS Microphones for Ground Testing of Aeronautical Systems

INNOVATION

Improving the acoustical environment is critical in aeronautics. Airports and aeronautical system manufacturers are facing ever-increasing demands to reduce noise levels. Aeronautical applications require the use of high-quality microphones with a large dynamic range, sometimes in large arrays. These arrays are expensive. The advent of lower cost microphones that meet users' specifications would dramatically improve the ability of engineers seeking to quantify the acoustic impact of their designs or their facilities (e.g., airports) and to make data-driven decisions to improve adverse situations.

The Phase 1 SBIR showed the technical feasibility of commercially viable, piezoelectric Microelectromechanical System (MEMS) microphones capable of withstanding the adverse conditions encountered while ground testing the acoustics of aeronautical systems. The Phase 2 project will implement design changes to improve these sensors, including the development of efficient deep reactive ion etching (DRIE) procedures to increase yield and lower costs. Scalable packaging techniques are being developed so that the devices can be economically assembled into a completed device. Finally, the reliability and robustness of these microphones will be determined. Each of these tasks will advance the goal of producing a commercially viable product with outstanding acoustical performance.

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Proposal # 09-2 A4.01-8257

OBJECTIVES

- ◆ Demonstrate two piezoelectric MEMS microphones, one suitable for scale model testing up to 100 kHz, and the second for full scale certification testing (20 kHz bandwidth)
- ◆ Improve yield in MEMS processing
- ◆ Determine microphone reliability
- ◆ Develop volume packaging capability

Work Plan

- ◆ Fabricate microphones
- ◆ Package microphones
- ◆ Optimize manufacturing process
- ◆ Analyze and test acoustics

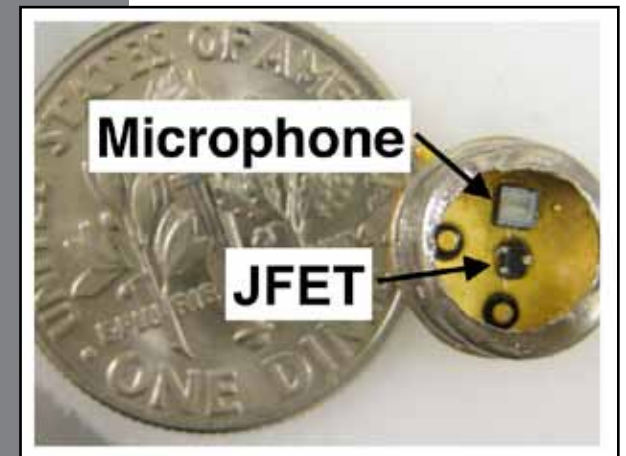
APPLICATIONS

NASA Applications

- ◆ Wind tunnel aero-acoustic measurements
- ◆ Engine test stand noise measurements
- ◆ Ground arrays for flight testing
- ◆ Anechoic room measurements
- ◆ Airport noise surveys
- ◆ Phased array systems

Non-NASA Applications

- ◆ Laboratory and studio-quality microphones
- ◆ Cell phone and other handheld communication devices
- ◆ Hearing aids and noise-cancelling headsets



A Novel, Portable, Projection, Focusing Schlieren System

INNOVATION

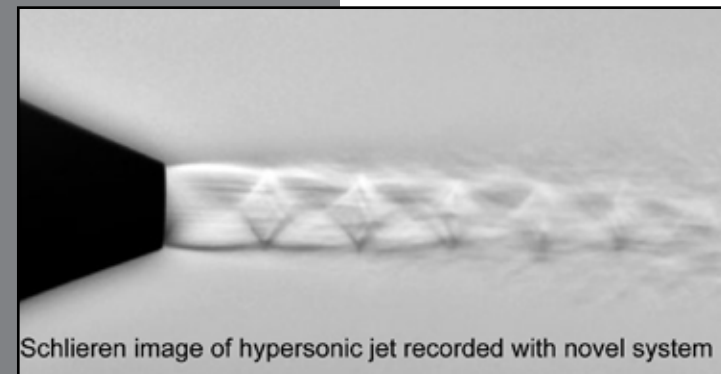
The schlieren technique has been used for flow diagnostics in wind tunnels since the beginning of aerospace research due to its ability to make airflows—especially shock waves and turbulence—visible. This proposal describes a novel type of schlieren system that would increase efficiency, capability, and productivity for ground test facilities. The concept and the availability of state-of-the-art components make the system more portable, easier to align, and more versatile than existing systems. A major drawback of current schlieren systems, and one that has restricted their widespread commercial use, is that they require exact alignment between a pair of widely separated mirrors or grids, which takes time and limits portability, and costs are prohibitive for most such applications. This problem is partially relaxed by focusing schlieren methods. The proposed concept incorporates features of existing schlieren systems while removing the primary limitations. All of the elements that require precise alignment are contained within a camera body and can be relatively inexpensive. Very large fields of view are made possible. This is advantageous in wind tunnel facilities, since experiments are frequently installed only to be torn down shortly afterwards.

OBJECTIVES

The primary objective of this project is to build a portable, adjustable instrument that can be used to obtain high-speed schlieren images and video of airflows that are of interest to the aerospace community. Key features are the ability to look at different fields of view, and selectively focus on limited depths of two-dimensional slices of a flow. MetroLaser, Inc., plans to build two prototype systems that will be improved versions of the Phase 1 breadboard system. At the 50 percent point of the program, the firm will demonstrate one system and deliver it to NASA. During the second half of the program, MetroLaser will upgrade the second prototype to incorporate new capabilities—for example, high-speed video, greater automation, or a larger field of view.

APPLICATIONS

Applications exist in all forms of research and development associated with flow fields where schlieren viewing could be useful, including aero-optics, flow control, drag, boundary layer transition, and flow separation. The proposed developments could be extremely important in enhancing ground test facility capabilities. Potential commercial applications include flow diagnostics of heating and ventilation systems.



Schlieren image of hypersonic jet recorded with novel system

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Proposal # 09-2 A4.01-8856

Fiber Optic Pressure Sensor Array

INNOVATION

VIP Sensors proposes to develop a Fiber Optic Pressure Sensor Array System for measuring airflow pressure at multiple points on the skin of aircraft for Flight Load Test applications. The array consists of multiple micro-miniature optical MEMS pressure sensors interconnected by a common optic fiber to an interrogation module located inside the airplane. The proposed optical pressure sensors are nearly flat, lightweight, fully passive (no electrical power), and EMI/RFI immune. They exhibit superior performance regarding accuracy, dynamic range, and noise. They are inherently self identifiable; the interrogation system knows what data belongs to what sensor.

The proposed sensor array technology is applicable to different types of optical sensors (accelerometers, strain, temperature, etc). Each sensor in the array is designed to work at preset optical wavelengths; they are read by the interrogation module using wave division and time division multiplexing.

Testing of aircraft requires a large number of sensors. Each sensor needs four to six wires to interconnect with signal conditioners. For large measuring systems, this means very large numbers of wires that add weight and occupy space. The proposed fiber optic (FO) sensor array system not only has the potential to significantly improve pressure measurements for Flight Load Testing, but its novel design of micro-miniature networking sensors will benefit many other aircraft ground and flight testing applications.

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Proposal # 09-2 A4.02-9523

OBJECTIVES

- ◆ Significantly improve the surface pressure measurement technology for Flight Load Test and Wind Tunnel Testing
- ◆ Improve the quality and reliability of measurements
- ◆ Reduce overall testing costs

Phase 1

- ◆ Prove that the proposed FO Pressure Sensor Array concept is feasible by analysis and laboratory concept demonstration
- ◆ Establish detailed technical requirements of the system to be designed and developed in Phase 2

Phase 2

- ◆ Design, develop, and build fully working sensor arrays ready for field evaluation and testing
- ◆ Develop and test the Interrogation System

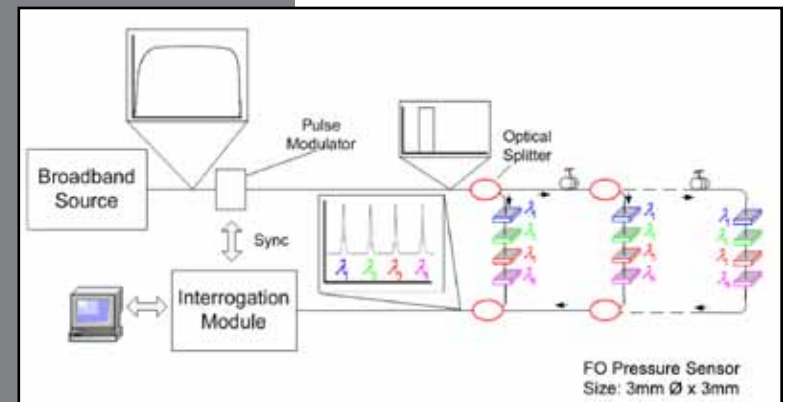
APPLICATIONS

NASA Applications

- ◆ In-flight and ground/wind tunnel testing of aircrafts where multiple surface pressure measurements are needed, such as the tests performed at the subsonic, transonic, and supersonic wind tunnel facilities, as well as the Flight Loads Laboratory (FLL) at NASA's Dryden Flight Research Center

Non-NASA Applications

- ◆ Aircraft Flight Testing
- ◆ Wind Tunnel Testing
- ◆ Airplane and Satellite Monitoring
- ◆ Ship Monitoring





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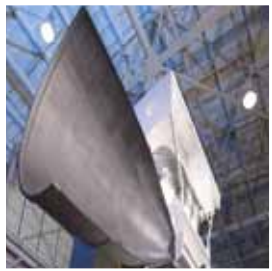
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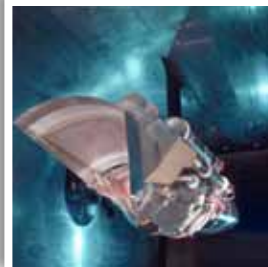
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